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ADCOCK'S SYLLABUS

OF A

COURSE OF EIGHT LECTURES

ON

MECHANICAL PHILOSOPHY,

INCLUDING NUMEROUS

RULES, TABLES, AND DATA,

WITH ILLUSTRATIVE

REMARKS FOR PRACTICAL APPLICATION.

BY HENRY ADCOCK,

CIVIL ENGINEER.

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TO

GEORGE BIRKBECK, M.D. F.G.S.

PRESIDENT

OF THE

LONDON MECHANICS' INSTITUTION,

OF THE

METEOROLOGICAL AND CHEMICAL SOCIETIES,

AND OF THE

MEDICAL AND CHIRURGICAL SOCIETIES OF LONDON,

HONORARY MEMBER

OF THE

LEEDS AND BRISTOL PHILOSOPHICAL SOCIETIES,

&c. &c. &c.

THIS WORK IS,

WITH SENTIMENTS OF THE HIGHEST ESTEEM, FOR HIS LITERARY ATTAINMENTS, HIS SCIENTIFIC EMINENCE, AND HIS NUMEROUS PUBLIC AND PRIVATE VIRTUES,

MOST RESPECTFULLY DEDICATED

BY THE AUTHOR.

ADVERTISEMENT.

Having been very frequently requested, by my friends and the public generally, to publish the Course of Lectures, which I am accustomed to deliver on Mechanical Philosophy; and not having, at this time, an opportunity of accomplishing it, I am induced to issue from the Press this small Book of Data.

I do this the more willingly, inasmuch as I have found that some persons, not possessed of the most honourable feelings, have published, in various periodicals, some of the information which I have been accustomed to impart, *almost verbatim;* and that too without making the slightest acknowledgment of the source whence it had been obtained.

It should be stated, however, that this Book is intended as an exposition of Data only. The hypothetical view of the nature and properties of heat, of steam, and of the gases—the detail of numerous interesting experimental investigations—the requisite proportions of good engines, of the various horses' power—and other highly valuable and important particulars, will be reserved until the publication of the Lectures, in two volumes octavo.

These, it is confidently hoped, will be issued from the press, in a few weeks from the present time.

Sept. 22*d*, 1832.

THE MECHANICAL POWERS.

PART 1.

THE INCLINED PLANE, THE WEDGE, AND THE SCREW.

THE INCLINED PLANE is a stationary instrument, along the surface of which, the weight to be raised is moved.

THE WEDGE is a movable inclined plane, used, commonly, to separate substances that are in contact with each other.

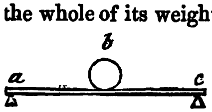
THE SCREW is an inclined plane, formed round the circumference of a cylinder: so that the weight, although moving along an inclined plane, may be made to proceed in a horizontal, or a vertical, or an oblique direction.

These three mechanical instruments are derived from the same property of matter: the greater or less support of a weight on planes of different inclinations.

This property may be thus explained:—

1.

If a substance, of any kind, be placed on the upper surface of a horizontal plane, the whole of its weight will be supported.



Thus b is supported by the plane a c.

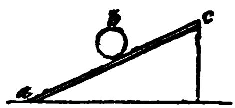
2.

If the plane be raised from the horizontal, into the vertical position, no portion of the weight will be sustained by it. The mass will therefore descend with the full amount of its gravity.

Thus b is not supported by the plane a c. It will therefore descend freely.

3.

If the plane be removed from the vertical, and placed in a slanting direction, in such manner, that its height be equal to half of its length, half of the weight will be supported.



Thus, half of the weight, b, is supported by the plane a c; consequently, man will only have to exert his strength against that portion of the weight which is unsupported.

4.

By the preceding investigations, we obtain the following rule, which is applicable to every inclined plane, wedge, or screw.

RULE.

By as many times as the length of the inclined plane exceeds its height, so will the weight raised exceed the power.

EXAMPLE.

The length of an inclined plane is 4 feet: its height, 1 foot. Hence, 1 lb. of power will maintain, in equilibrium, 4 lbs. of weight.

REMARKS.

The inclined plane, the wedge and the screw, although derived from the same property of matter, and, in fact, are different modifications of the same principle, usually have separate rules assigned to them in mechanical treatises.

These rules we shall now present. But it should be stated, that the diminution of effect, by friction, is not included.

THE INCLINED PLANE.

CASE I.

To find the POWER *that will raise a given weight:—the length and height of the plane being known.*

RULE.

Multiply the weight by the height of the plane, and divide the product by its length.

EXAMPLE.

Length of the plane...............	54 inches.
Height of ditto	18 inches.
Weight to be raised	66 lbs.

$$\text{Hence } \frac{18 \text{ ins.} \times 66 \text{ lbs.}}{54 \text{ ins.}} = 22 \text{ lbs.}$$

The power will be 22 lbs. to support the weight.

CASE 2.

To find the WEIGHT *that will be raised by a known amount of power, the length and the height of the plane being given.*

RULE.

Multiply the power by the length of the inclined plane, and divide the product by its height.

EXAMPLE.

Length of the plane.................	8 feet.
Height of Ditto	2 feet.
Power to be applied	50 lbs.

$$\text{Hence } \frac{8 \text{ feet} \times 50 \text{ lbs.}}{2 \text{ feet.}} = 200 \text{ lbs.}$$

The weight to the power, therefore, is as 200 to 50, or as 4 to 1.

CASE 3.

To find the LENGTH *of an inclined plane, to raise a given weight:—when its height, and the power to be applied, are known.*

RULE.

Multiply the height of the inclined plane, by the weight; and divide the product by the power.

EXAMPLE.

Height of the plane .... $4\frac{1}{2}$ feet.
Weight to be raised.................. 200 lbs.
Power to be applied.................. 60 lbs.

$$\text{Hence } \frac{4\frac{1}{2} \text{ feet} \times 200 \text{ lbs.}}{60 \text{ lbs.}} = 15 \text{ feet.}$$

The length of the required plane will be 15 feet.

CASE 4.

To find the HEIGHT *of an inclined plane, to raise a given weight:—its length, and the power to be applied, being known.*

RULE.

Multiply the length of the inclined plane, by the power; and divide the product by the weight.

EXAMPLE.

Length of the plane .... 15 feet.
Power to be applied .... 60 lbs.
Weight to be raised .... 200 lbs.

$$\text{Hence } \frac{15 \text{ feet} \times 60 \text{ lbs.}}{200 \text{ lbs.}} = 4\frac{1}{2} \text{ feet.}$$

The height of the plane will be $4\frac{1}{2}$ feet.

9

THE WEDGE.

The wedge, when the power is applied at its back, in a continuous manner, and not by a succession of blows, assimilates to the inclined plane. It is, in short, a movable inclined plane.

The rules, therefore, which are given for the "INCLINED PLANE," are equally applicable to the wedge.

But the power is commonly imparted to this instrument by a succession of blows or strokes. Those blows produce percussive force. Percussive force has not, as yet, been properly investigated; and until such investigations shall have taken place, we cannot, with propriety, assign a rule to the wedge.

The following rules, with such modifications as we have conceived necessary, are usually inserted in elementary treatises.

CASE 1.

To find the power and effect of the single wedge: the power being applied continuously.

RULE.

As the length of the inclined surface of the wedge, is to the height of its head or back; so is the resistance to the power.

EXAMPLE 1.

Length of the plane, ... 10 inches.
Height of the back, ... 3 inches.
Resistance, ... 150 lbs.

As 10 : 3 : : 150 : 45 lbs.

The power is 45 lbs.

EXAMPLE 2.

Length and height of the plane as before.

Power 45 lbs.

As 3 : 45 : : 10 : 150 lbs.

The resistance is 150 lbs.

This rule is another expression for the rules of the inclined plane.

To find the power an
two equal surfaces, on i
the power being applied

By this wedge, two l
equal distances from th

As the length of eitl
wedge, is to half the h
resistance to the power.

Length of the p
Half height of t
Resistance, ...

Hence, 10 :
The power r

The resistance of 150
with a force of 75lbs.
power to each plane, or

In this example, the
in Case 1. For the re
planes, both being of
half of the height,
wedge.

Length of the
Half height o
Power to be s

As 1
The R

THE SCREW.

The Screw is an Inclined Pline, formed round the circumference of a cylinder.

The Height of the Inclined Plane is the distance from the upper surface of one thread of the Screw, to the upper surface of the next:—

The Length is the extent of the spiral line between those surfaces, or in one revolution of the circumference.

GEOMETRICALLY, the length of the inclined plane is the hypothenuse of a triangle:—the base being equal to the circumference of the cylinder; its height to the distance between two consecutive chords, or threads.

Hence, the nearer the spirals are to one another, the greater the power of the screw.

Power is usually imparted to the screw, through the interposition of the lever or winch. It but rarely occurs that we have occasion to calculate its power in a simple or uncompounded state.

When compounded with the lever or winch, the difference of power and effect may be thus determined:—

RULE 1.

By as many times as the circumference, described by the lever in its rotation, is greater than the interval or distance between two threads of the screw; so will the weight raised exceed the power.

EXAMPLE.

Circumference of circle $=$ 48 inches.
From thread to thread $=$ $\frac{1}{2}$ inch.

Hence, 48 $\times$ 2 half-inches $=$ 96.
The weight to the power is as 96 to 1.

RULE 2.

Multiply the circumference of the circle described by the lever or winch, by the power that is to be applied; and divide the product by the distance from the upper surface of one thread of the screw, to the upper surface of the next.

EXAMPLE.

Circumference of circle	30 inches.
From thread to thread............	1 inch.
Power to be applied	12 lbs.

$$\text{Hence } \frac{30 \text{ inches} \times 12 \text{ lbs.}}{1} = 360 \text{ lbs.}$$

The weight raised will be 360 lbs.

REMARKS.

The screw is one of the most valuable of the mechanical powers. It is much used as a dividing instrument. Many eminent men, therefore, have devoted much time and attention to its improvement.

To the late Henry Maudslay, Esq. of the celebrated firm of Messrs. Maudslay, Son, and Field, engineers, of London, we are indebted for the most perfect screws which have been, as yet, manufactured. By the talent, the ingenuity, and the unremitting perseverance of that late distinguished individual, we have obtained screws, which do not deviate from accuracy throughout their length, more than the fifteen-hundredth part of an inch.

We have stated the screw to be an inclined plane, formed round the circumference of a cylinder. In the most perfect screw, made at this establishment, if it were possible to unwind this plane from the cylinder, and stretch it out, it would extend 1800 feet in length. The screw, however, on which it is formed, is only four feet six inches in height.

Let the reader conceive the difficulty of making a board of wood, or a piece of metal, 1800 feet in length, so perfect on its surface, that not one part of it shall be higher than another, more than the fifteen-hundredth part of an inch. Then let him conceive the difficulty of cutting an inclined plane round a solid cylinder of brass, so as to form the thread of a screw; and in such manner, that not one part of it shall deviate in accuracy from another, more than we have stated: that is, more than the fifteen-hundredth part of an inch, in a length of 1800 feet. He will then possess some idea of the astonishing degree of perfection attained in these screws.

Suppose that one of these screws be made with 50 threads in an inch; and that the inclined plane, or the length of the spiral line between two chords or threads, be 4 inches,

Then 4×50, or 200 inches,

must be passed through by an object moving along the inclined plane, by the time it has reached the height of one inch on the screw.

Suppose, further, that a circular piece of metal, 10 inches in circumference, be fixed firmly on the axis, or on one end, of the screw; and that each inch of that circumference be divided into 50 equal spaces.

Then there will be 10×50, or 500 divisions on the circle.

Hence, if the circle, instead of making an entire revolution, be moved through one division only, the object will move along the inclined plane of the screw, the hundred-thousandth part of an inch.

For $200 \times 500 = 100{,}000$.

In other words, the circumference of the circle must pass before an index, a hundred thousand of its divisions, before an object, moving along the screw, will have attained the height of one inch.

It is thus that the screw is used as a dividing instrument.

PART II.

THE LEVER,
THE WHEEL AND AXLE,
AND THE PULLEY.

THE LEVER is a bar of wood, or other substance, resting on a support, termed the fulcrum.

THE WHEEL AND AXLE is formed of a series of levers, so fixed on a fulcrum, as an axis, that they can rotate or describe circles around it.

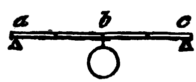
THE PULLEY is a cord, or a series of cords, having, like the lever, certain places of support.

These three mechanical instruments, similarly to the inclined plane, the wedge, and the screw, are also derived from one property of matter: the distribution of a weight on the ends of a bar.

This property may be thus explained :—

1.

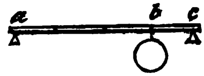
If a weight be placed on the middle of a bar, it presses with equal force on the ends.



Thus, the weight, b, presses equally, and with half the amount of its weight, on each of the supports, a and c.

2.

If the weight be now removed from the middle of the bar, and be placed towards either end; so that it be at one-fourth of the length of the bar from one support, and at three-fourths from the other, the pressure on the supports will be *inversely* as their distances from the weight.



Thus, c supports three-fourths of the weight; a, one-fourth.

INVERSELY AS THE DISTANCES, may be thus explained:—

1.

$\frac{1}{4}$ of length supports $\frac{3}{4}$ of weight = 1
$\frac{3}{4}$ of length............ $\frac{1}{4}$ of weight = 1

2.

$\frac{1}{3}$ of length supports $\frac{2}{3}$ of weight = 1
$\frac{2}{3}$ of length............ $\frac{1}{3}$ of weight = 1

3.

$\frac{1}{6}$ of length supports $\frac{5}{6}$ of weight = 1
$\frac{5}{6}$ of length............ $\frac{1}{6}$ of weight = 1

EXAMPLE.

A man and boy find it necessary to carry, or support, by their united exertion, a weight of 120lbs. The man for a short time, can exert a force of 100lbs.: the boy 20lbs. The boy, therefore, can exert one-sixth of the weight: the man five-sixths. Hence, the weight should be placed on the bar, at one-sixth of its length from the man.

For $\frac{1}{6}$ of length = $\frac{5}{6}$ of weight = 100lbs—Man.
$\frac{5}{6}$ of length = $\frac{1}{6}$ of weight = 20lbs—Boy.

By this arrangement, the man and boy exert, relatively, their proportionate strengths.

REMARKS.

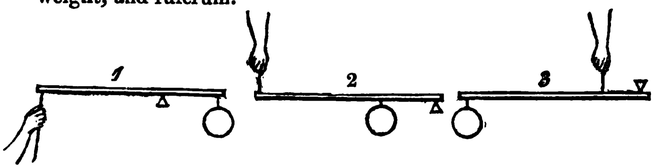
Let the end of the bar be removed from the man, and placed on some inert substance: that substance will then sustain the weight heretofore supported by the man. The boy is still subjected to the pressure of 20lbs. If the boy, therefore, exert rather more than 20lbs. of power, he will be able to raise his end of the bar. Corresponding to that elevation, taking into account the difference of the length of the bar from the place of support, will be the elevation of the weight. Hence, the boy, by exerting rather more than twenty pounds, can raise a hundred and twenty. This is the principle of the lever.

The inert substance, or support, is termed the fulcrum.

THE LEVER.

The Lever may be made to assume three positions. Those positions have given rise to the several denominations, of Lever of the first, second, and third kind.

The several denominations, or classes, may be distinguished by paying atttention to the relative positions of the power, weight, and fulcrum.



1st Class.—Power——Fulcrum—*Weight.*

2d Class.—Power——*Weight*——Fulcrum.

3d Class.—*Weight*—Power ——Fulcrum.

In the *Lever of the First Class*, the power is at one end of the bar; the weight at the other; and the fulcrum is placed somewhere in the intermediate space between them.

In the *Lever of the Second Class*, the relative positions of the fulcrum and weight are changed.

In the *Lever of the third Class*, the weight changes place with the power.

By this, we may assume, that the denominations of the classes have been produced by the progressive advancement of the weight along the bar. In the Lever of the First Class, it is at one end; in the Lever of the Second Class, it is in the intermediate space; in the Lever of the Third Kind, it is at the other end.

Hence, the three kinds of Lever may be readily known, by paying attention to that which is in the intermediate space between the ends of the bar. When the fulcrum is there, it is a Lever of the first kind; when the weight is there, it is a lever of the second kind; and when the power is there, it is a Lever of the third kind.

The power and effect of the different kinds of Lever may be thus determined.

CASE I.

To find the position of the Fulcrum, *to raise a given weight, by a known amount of power.*

RULE.

Divide the weight to be raised by the power to be applied: the quotient will exhibit the difference of leverage necessary to support the weight in equilibrium.

EXAMPLE.

Weight to be raised......42 cwt.
Power to be applied ...... 6 cwt.

Hence, $42 \div 6 = 7$,

The distance from the power to the fulcrum, therefore, must be seven times greater than from the fulcrum to the weight.

For $\frac{1}{7}$ of length $= \frac{6}{7}$ of weight $=$ 36 cwt.—Fulcrum.
$\frac{6}{7}$ of length $= \frac{1}{7}$ of weight $=$ 6 cwt.—Power.

CASE 2.

To find the Weight *that will be raised by a known amount of power, the position of the fulcrum being given.*

RULE.

Multiply the distance between the power and the fulcrum, by the power; and divide the product by the distance between the fulcrum and the weight.

EXAMPLE 1.

A bar 10 feet long is arranged as a Lever of the first kind.

From power to fulcrum .... $8\frac{3}{4}$ feet.
From fulcrum to weight .... $1\frac{1}{4}$ foot
Power to be applied .... 40 lbs.

$$\text{Hence } \frac{8\frac{3}{4} \text{ feet} \times 40 \text{ lbs.}}{1\frac{1}{4} \text{ foot.}} = 280 \text{ lbs.}$$

The weight raised will be 280 lbs.

EXAMPLE 2.

The same bar is arranged as a Lever of the second kind.

From power to fulcrum................ 10 feet.
From weight to fulcrum .... $1\frac{1}{4}$ foot.
Power to be applied .... 40 lbs.

$$\text{Hence } \frac{10 \text{ feet} \times 40 \text{ lbs.}}{1\frac{1}{4} \text{ foot.}} = 320 \text{ lbs.}$$

The weight raised will be 320 lbs.

For $1\frac{1}{4}$ foot is one-eighth of the length of the Lever.

Hence $\frac{1}{8}$ of length $= \frac{7}{8}$ of weight $=$ 280 lbs. Fulcrum.
$\frac{7}{8}$ of length $= \frac{1}{8}$ of weight $=$ 40 lbs. Power.

320 lbs. Weight.

EXAMPLE 3.

The same bar is arranged as a Lever of the third class.

From weight to fulcrum............... 10 feet.
From power to fulcrum............... 2 feet.
Power to be applied .... 30 lbs.

$$\text{Hence } \frac{2 \text{ feet} \times 30 \text{ lbs.}}{10 \text{ feet.}} = 6 \text{ lbs.}$$

The weight raised or maintained in equilibrium will be 6 lbs.

A small addition of power, therefore, in this example, or of either power or leverage, in examples 1 and 2, will cause th power to preponderate.

CASE 3.

To find the POWER *that will raise a given weight: the position of the fulcrum being known.*

RULE.

Multiply the distance between the weight and the fulcrum, by the weight to be raised; and divide the product, by the distance between the fulcrum and the power.

EXAMPLE 1.

Lever of the First Class.

From power to fulcrum, ...	8 feet.
From weight to fulcrum,............	2 feet.
Weight to be raised,..................	252 lbs.

Hence, $\dfrac{2 \text{ feet} \times 252 \text{ lbs.}}{8 \text{ feet.}} = 63$ lbs.

The power to be applied is 63 lbs.

EXAMPLE 2.

Lever of the second kind.

From power to fulcrum, ...	10 feet.
From weight to fulcrum, ...	2 feet.
Weight to be raised,..................	252 lbs.

Hence, $\dfrac{252 \text{ lbs.} \times 2 \text{ feet}}{10 \text{ feet.}} = 50\frac{4}{10}$ lbs.

The power in this example will be $50\frac{4}{10}$ lbs.

EXAMPLE 3.

Lever of the third kind.

From power to fulcrum, ...	1 foot.
From weight to fulcrum, ...	10 feet.
Weight to be raised, ...	15 lbs.

Hence, $\dfrac{10 \text{ feet} \times 15 \text{ lbs.}}{1 \text{ foot}} = 150$ lbs.

The power will be 150 lbs.

THE WHEEL AND AXLE.

The wheel and axle may be supposed to be generated, by causing a lever to rotate, or describe circles, around its fulcrum. The circle described by the longest arm of the lever, represents the wheel; that by the smaller arm, the axle. Hence, the wheel and axle is nothing more than a lever in rotation; and, of course, it is dependant on the same laws.

The rules which we have given for the lever, are, therefore, equally applicable to the wheel and axle, and the winch and axle.

The following is another mode of expressing the same rules.

RULE.

As the radius of the wheel, is to the radius of the axle; so is the weight to the power.

EXAMPLE 1.

Power is applied to the periphery of a wheel, to raise a weight attached to a cord: the cord being fastened to an axle.

Radius of wheel, ... 5 feet.
Radius of axle, ... 20 inches.
Power to be applied, ... 50 lbs.

5 feet = 60 inches.

As 20 : 60 :: 50 : 150 lbs.

The weight will be 150 lbs.

EXAMPLE 2.

Weight to be raised, ... 150 lbs.
Power to be applied, ... 50 lbs.
Radius of wheel, ... 60 inches.

As 150 : 50 :: 60 : 20 inches.

The radius of the axle will be 20 inches.

THE PULLEY.

The pulley is of two kinds. The one consists of a series of cords attached to a beam, and to one another: the other of a single cord, passing, alternately, over and under a series of sheeves, or friction wheels. Both are derived from the same property of matter: the distribution of a weight on certain points of support.

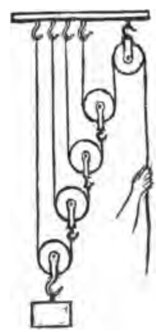
CASE 1.

To find the power and effect of a pulley, consisting of a series of cords.

RULE.

Double the power at the first cord, or point of suspension; and continue to double the amount at every subsequent suspension.

EXAMPLE.



Required the weight that can be raised by one pound of power: the pulley having four cords.

1st cord—1 lb. × 2 = 2 lbs.
2nd cord—2 lbs. × 2 = 4 lbs.
3rd cord—4 lbs. × 2 = 8 lbs.
4th cord—8 lbs. × 2 = 16 lbs.

The weight that can be maintained in equilibrium, on the fourth cord, is 16lbs.

REMARKS.

According to the equal distribution of a weight on the ends of a bar, as shown in page 14, the 16 lbs. are thus disposed:

4th cord, 8 lbs. on beam + 8 lbs. on 3rd cord.
3rd cord, 4 lbs. on beam + 4 lbs. on 2nd cord.
2nd cord, 2 lbs. on beam + 2 lbs. on 1st cord.
1st cord, 1 lb. on beam + 1 lb. on power.

Hence, 15 lbs. are supported by the beam. Man, therefore, has only to exert 1 lb. of power to suppor the remaining 1 lb. of weight.

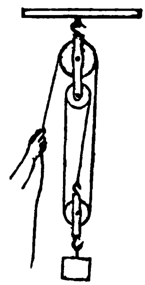
CASE 2.

To find the power and effect of a pulley, formed of a single cord, passing, alternately, over and under a series of sheeves.

RULE.

Count the number of apparent lines connected with the lowest block of sheeves: these will indicate the difference between the power and the weight.

EXAMPLE 1.

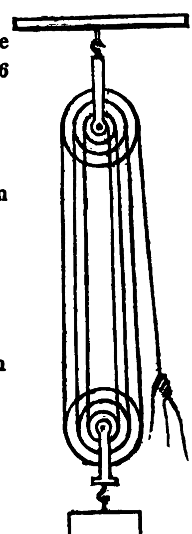


Required the weight that can be raised by 15 lbs. of power: the pulley having, apparently, three cords attached to the lowest block.

15 lbs. $\times$ 3 $=$ 45 lbs.

The weight will be 45 lbs.

EXAMPLE 2.



What amount of power is required, to raise 240 lbs:—the pulley possessing, apparently, 6 cords.

240 lbs $\div$ 6 $=$ 40 lbs.

The power required to maintain the weight, in equilibrio, will be 40 pounds.

EXAMPLE 3.

The pulley being the same, what weight can be raised by 12 lbs. of power.

12 lbs. $\times$ 6 $=$ 72 lbs.

The weight will be 72 lbs.

ANIMAL POWER.

In investigating the strengths of animals, there are three circumstances which demand attention :—

First—The power, when the strength of the animal is exerted against a resistance that is at rest.

Secondly—The power, when the stationary resistance is overcome, and the animal is in motion.

And Thirdly—The power, when the animal has attained the highest amount of its speed.

In the first case, the animal exerts not only its muscular force or strength, but, at the same time, a very considerable portion of its weight, or gravity. The power, therefore, from these causes, must be the greatest possible. In the second case, some portion of the power of the animal is withdrawn, to maintain its own progressive motion :—consequently, the amount of useful labour varies with the variations of speed. In the third case, the power of the animal is wholly expended in maintaining its locomotion. It therefore can carry no weight.

From the theoretical and practical investigation of these principles, the power of man and the horse, at a maximum, and under various other useful positions, may be known.

RULE.

When an animal moves with one-third of its greatest speed, and is loaded with four-ninths of the greatest weight it is capable of putting in motion, its power is at a maximum.

In other words, the animal will then do the greatest quantity of effective labour.

SPEED.

The greatest speed of man, and of the draught or cart horse, are, on the average, exactly equal to one another; both being able to move at the rate of seven and a half miles in an hour.

This is an extraordinary coincidence; and, in our opinion, tends to disprove the notions inculcated by some metaphysicians, that socicty is, at this time, in an artificial state.

WEIGHT.

When moving at great speeds, the following weights can for a short time be exerted:—

By man .... 61·364 or $61\frac{4}{10}$ lbs.,
By the horse ... $337\frac{1}{2}$ lbs.

MAXIMUM.

Hence, both man and the horse, to perform the greatest amount of useful labour, day by day, without experiencing distress, or rendering themselves liable to physical derangement, must, agreeably with the foregoing rule and subsequent observations, move at the rate of $2\frac{1}{2}$ miles in the hour; and carry $27\frac{1}{4}$ lbs., and 150 lbs. respectively—

For $\frac{1}{3}$ of $7\frac{1}{2}$ miles $=$ $2\frac{1}{2}$ miles.

$\frac{4}{9}$ of 61.364 lbs $=$ 27·273 lbs. $=$ Man.
$\frac{4}{9}$ of $337\frac{1}{2}$ lbs $=$ 150 lbs. $=$ Horse.

27 lbs. 273 decimal, for man, is, in amount, rather more than $27\frac{1}{4}$ lbs.

The power exerted at other rates of speed, and the diminution of useful effect by such changes, may be thus exhibited:—

MAN AND HORSE POWER.

SPEED.	MAN.		HORSE.	
per hour.	*lbs. dec.*	*action.*	*lbs. dec.*	*action.*
1 Mile	46 · 091	4056	253 · 50	22,308
2 Miles	32 · 864	5784	180 · 75	31,812
$2\frac{1}{2}$ Miles	27 · 273	6000	150 · 00	33,000
3 Miles	22 · 091	5832	121 · 50	32,076
4 Miles	13 · 364	4704	73 · 50	25,872
5 Miles	6 · 818	3000	37 · 50	16,500

The action is obtained by multiplying the pounds carried, by the feet passed through in a minute.

The great diminution of effect, at speeds much greater or much less than the maximum, shows to us the necessity of ascertaining, with some care, the speeds and strengths of men and horses.

If two horses of equal strengths and equal speeds be employed, the one moving at the rate of $2\frac{1}{2}$ miles in an hour, and the other at 5 miles; then, if both horses, when moving at those speeds be weighted proportionately to their respective strengths, the quickest horse will only produce half the quantity of effective labour of the other. For the action of the one horse, by the foregoing table, is 16,500; of the other, 33,000.

The same observations are applicable to man.

From the table, as a further elucidation, we shall extract the following:—

At $2\frac{1}{2}$ miles per hour.

The power of man is $27\frac{1}{4}$ lbs. or 27·273.
That of the horse, 150 lbs.

At 5 miles per hour.

Man can only exert $6\frac{8}{10}$ lbs., or 6·818.
And the horse,.. ... $37\frac{1}{2}$ lbs.

Hence, we learn, when the speed of the animal is increased to twice that of the maximum, the quantity of useful power is reduced to one-fourth. In the higher velocities, a very small amount of additional weight will materially retard the speed.

So great is the value of a knowledge of this property, that large sums of money have been made by it, on the race-course. A difference of seven pounds of weight, on horses of equal strength, and of thorough blood, will, in a four-mile course, produce a difference of a hundred and forty yards. This shews, in a striking manner, the necessity of paying some attention to these much neglected circumstances.

Diminished speeds are similarly attended with loss to the proprietor. This will be observed by an examination of the columns of action, in the last page.

MAN POWER WITH MACHINERY.

Pounds moved × feet per minute = Action.

How employed.	*Power.*	*Action*		*Ratio.*	
	Lbs. Dec.	Pr Min.	Pr. Hour.	Men Dec.	Men Dec.
Lifting or carrying	27·273	6000	360,000	10·00	10·00
Turning a winch	28·637	6300	378,000	10·50	9·52
Turning a winch in conjunction with another man, the handles being at right angles to each other, each man will exert	33·409	7350	441,000	12·25	8·16
Pumping	17·335	3843	230,580	6·40	15·61
Ringing	38·955	8570	514,200	14·28	7·00
Rowing	40·955	9010	540,600	15·00	6·66

Col. 1, exhibits the power, in pounds and decimal fractions, that a man of the average strength can exert, when moving at the rate of 2½ miles per hour.

Col. 2, shews the action, or the number of lbs. which each man, can raise on the average, through 1 foot in a minute.

Col. 3. The action per hour, obtained by multiplying col. 2 by 60 minutes. Man, from the above considerations, is supposed to work ten hours per day. A cypher, added to the several amounts in col. 3, will furnish the respective actions in a day. Thus 360,000 will become 3,600,000.

Col. 4, shews the quantity of useful labour that 10 men will perform, when compared with the direct action in lifting, or carrying. When lifting, these 10 men will perform the action of 10; but, in rowing a boat, these ten men can exert as much power, or do as much effective labour, as can be accomplished, in the same time, by 15, when lifting. The causes will be subsequently explained.

Col. 5, exhibits the number of men that must be employed in the several departments, to produce an equal quantity of labour with 10 men, in lifting. In the ringing of church bells, seven men, by the column, will be found sufficient.

OBSERVATIONS. The increase and decrease of effect in these various positions, may be thus explained:

THE WINCH, in its revolution, describes a circle: at two points of which the power of man is employed to a very great advantage; and at two others, to a disadvantage. The power is advantageously applied when the winch handle is at the highest and the lowest parts of the circle. Man, at those times, thrusts it from, or draws it towards him, exerting with his muscular force, or energy, some portion of his weight; and these forces continue to act upon it, until it is within a certain angle of the top and bottom. The power of the workman is then employed to a disadvantage: he has to recover the balance which, in the prior exertion, he had lost. The advantages, however, so far exceed the disadvantages, that man can raise 6300 lbs. with the winch, and without any regard to leverage, with the same ease that he can raise 6000 lbs. by direct means.

When men are employed at a winch with two handles, the handle on one side being at the highest point of the circle, while that on the other is at the lowest, those men are working advantageously and disadvantageously at similar periods with each other: consequently, each man will exert 6300 lbs. as above stated. But, if the winch handles be placed at right angles, or at angles varying from 90° to 120°, the workmen on the one side will be acting to advantage, while those on the opposite are to the reverse: the men, therefore, will be mutually beneficial to each other. Under these circumstances, each person will exert 7350 lbs. with precisely the same expenditure of power, as was before necessary for 6300:—105 men effecting as much useful labour, in the course of the day, as was before accomplished by 123.

IN PUMPING, the diminution of effect is produced, partly by the time lost in raising the handle: and partly by the friction of the bucket.

IN RINGING and ROWING, man compounds some portion of his weight with his muscular energy.

Hence, the differences between those numbers, or 140 degrees of heat, are absorbed, or rendered latent, during the liquefaction of ice;

$$\text{For } 172^\circ - 32^\circ = 140^\circ,$$

By absorbing 140° of caloric, ice becomes liquid; and by withdrawing a similar quantity, it again becomes solid: and thus the changes alternately are effected.

Similar results, ensue, in the generation of steam.

LATENT HEAT OF STEAM.

If equal quantities of water, at 212° and 32°, respectively, be mixed together, the thermometer will indicate the arithmetical mean of the mixture, or 122°.

$$\text{For, 1 oz. water at } 212^\circ + \text{1 oz. water } 32^\circ = 244^\circ.$$

$$\text{And } 244^\circ \div \text{2 ozs.} = 122^\circ.$$

The arithmetical mean, will also be produced, by an admixture of the following quantities:

$$\text{1 oz. water at } 212^\circ + \text{11 ozs. of water at } 32^\circ.$$

$$\text{11 ozs.} \times 32^\circ = 352^\circ.$$

$$\text{And } \frac{212^\circ + 352^\circ}{\text{12 ozs.}} = 47^\circ$$

But, if an ounce of *steam* at 212°, be mixed with the same quantity of water as before stated, and at the same temperature, a very different result will be yielded: the thermometer will range to $127\frac{5}{6}$°.

Hence, the difference between those respective temperatures, multiplied by the ounces employed, will furnish us with the heat, or caloric, absorbed by the steam in a latent state.

$$\text{For, } 127\tfrac{5}{6}^\circ - 47^\circ = 80\tfrac{5}{6}\text{; and } 80\tfrac{5}{6} \times \text{12 ozs.} = 970^\circ.$$

CALORIC IN STEAM.

From the preceding investigations, we shall extract the following:—

Thermometric heat of steam, ...	212°
Latent heat of do. at 212°..................	970°
Latent heat of water, ...	140°
Caloric in Steam	1322°

Steam, therefore, although indicating but 212°, by the thermometric scale, does actually contain 1322°. But, as the 140° of heat, absorbed during the liquefaction of ice, is not imparted to any surrounding object until the water is again congealed, we should, in practical application, consider steam as possessing the two former quantities only, or 1182 degrees.

It should, however, be stated, that the 970° of heat which are latent in steam, do not imply, according to this hypothesis, that the mercurial column of the thermometer should range to that elevation; but that each vesicle of steam is of such capacity, that it can contain within the film of water by which it is surrounded, rather more than 4½ times the quantity of caloric contained in the film itself.

Taking the quantity of caloric in the film of water at 1, or unity, the statement may be thus exhibited:—

Film of water at 212° × 1 quantity	=	212°
Within ditto, 4½ quantities × 212° = 954°		
Omitted, the film containing rather more than 4½ times the quantity at 212°	= 16	970°
Caloric in steam at 212°		1182°

The temperature, therefore, within the vesicle, as also of the water which forms its film, or external covering, is the same. The 1182° are obtained, by multiplying 212° by the vesicular quantities.

PASSAGE OF CALORIC.

The hypothesis is founded on the supposition, that caloric is material. That it is so, appears extremely probable. For, Caloric, or heat, passes through the pores of a metallic substance, as a boiler, in equal quantities in equal times.

To raise water from 50° of temperature, to 212° or the boiling point; and subsequently, to evaporate the same quantity into steam; effects similar to the following ensue:—

1 lb. water at 50° raised to 212° in 4 minutes.

1 lb. water at 212, evaporated in 24 minutes.

The times occupied, agreeing exactly with the relative proportions of caloric.

For $212° - 50° \quad = 162°$ Thermometric Heat.
And $162° \times 6$ times $= 972°$ Latent Heat, $+ 2°$.

The water, in the first place, is raised from 50° to 212°, or receives an influx of 162° of caloric: it is then changed into steam. In receiving the 162°, four minutes are occupied: and, during the evaporation, six times that quantity. Because, the steam indicates the same thermometric temperature as the water, from which it has been generated, and receives only an influx of the heat which is latent—the latent heat being 970°.

CAPACITY FOR HEAT.

Water, and every kind of liquid, seems to possess a certain capacity for heat. This capacity varies with the varying pressure to which the liquid is exposed. In England, under the ordinary atmospheric pressure, the capacity of water, or its boiling point, is at 212°: at Chili, situate high in a mountainous district, it boils at 196°: in some parts of France, the temperature of ebullition is at 210°. And variations might be adduced in other places, by reference to the elevations of the atmospheric column.

The boiling point of a liquid, being dependant on the pressure, may be altered, very materially, by mechanical arrangements.

Beneath the exhausted receiver of an air-pump, water can be made to boil at a very low temperature: in a high pressure boiler, the temperature of ebullition can be carried to any required height, compatible with the safety of the vessel.

Under the ordinary atmospheric pressure of this kingdom, the boiling points of some of the most important liquids may be thus exhibited.

BOILING POINTS.

98°	Ether.	248°	Nitric Acid.
140°	Liquid Ammonia.	560°	Oil of Turpentine.
176°	Alcohol.	212°	Do. do. (Dalton.)
212°	Water.	590°	Sulphuric Acid.
212°	Essential Oils.	600°	Linseed Oil.
242°	Nitrous Acid.	660°	Mercury.

THE STEAM ENGINE.

HORSE POWER.

Much discrepancy of opinion has, for a long time past, been current upon this important subject. The statements of Desagulier, Smeaton, and Watt, have been advanced by the various authors, without their making any attempt to reconcile them, or to prove the fallacies of either.

The horse power, when compared by the action, or by the number of pounds which can be raised through one foot in a minute, is, according to these celebrated individuals, usually thus stated:—

Dr. Desagulier ....44,000 lbs.
Mr. Smeaton ....22,000 lbs.
Mr. Watt.......................33,000 lbs.

Furnishing, certainly, most extraordinary apparent differences of result.

But these statements, however discordant they may appear when thus tabulated, will be found, on subsequent investigation, practically to coincide.

Dr. Desagulier states, expressly, that the action, 44,000, was produced when the horse was working but 8 hours per day: the duration implied by Smeaton and Watt is 10 hours. The 44,000, therefore, must be distributed over the greater time.

The observations of Mr. Watt bear relation to a dead weight drawn over a pulley; consequently, to the direct action of lifting. Those adduced by Mr. Smeaton to the more limited action when pumping. The relative value of those actions are thus given at page 26, for man power.

When lifting,.........6000
When pumping,......3843

The actions of the horse, we may presume, are nearly, but not quite in the same ratio. For, when this useful animal is employed, under the same circumstances, some of those impediments which necessarily resulted to man, from his organization, are removed. But then, the horse encounters others, from which man is exempt, by the peculiar mechanical

arrangement, through which the power is applied. Altogether, we think it extremely probable that the one effect nearly counterbalances the other; at least, sufficiently so to account for the slight difference of result in the subjoined card of direct action:

$$\text{Dr. Desagulier, } \frac{44{,}000 \times 8}{10 \text{ hours.}} = 35{,}200$$

$$\text{Mr. Watt, direct action, } = 33{,}000$$

$$\text{Mr. Smeaton, } \frac{22{,}000 \times 6000}{3843} = 34{,}348$$

The actions, when thus exhibited, being closely approximative.

In several of the treatises which have been written on this subject, it is contended, that Mr. Watt defined the horse power of the steam-engine, by conducting a series of experiments on some of the large and powerful horses, employed by the London brewers. This statement, also, is currently believed by practical men. We, however, entertain a different opinion.

By the preceding investigations we have shown, notwithstanding the former apparent discrepancies, that Smeaton, Desagulier, and Watt, make the average power of the horse nearly, if not quite the same, in direct action: and the result agrees within a fraction with the results furnished by other experimentalists. This power is equal to that of 5½ men.

Now, we have no hesitation in expressing it to be our opinion that the horses employed by the London brewers possess the power of seven men. Mr. Watt, therefore, could not have formed the horse-power by them. On the contrary, we believe that he pursued a similar train of investigation as ourselves.

We find that the horse, when working at a maximum, moves at the rate of 2½ miles per hour, or 220 feet in a minute; and carries, or otherwise exerts, 150 lbs. Mr. Watt must have been aware of this maximum of effect, first pointed out by Euler. For, he has compelled the piston of the steam-engine to move at the same rate, precisely, or at 220 feet per minute; and then for every 150 lbs. of effective pressure of steam, acting upon it, he has assumed a horse's power. Hence, the horse-power of the steam-engine, and the maximum effect of the living animal, are exactly equal to one another.

The HORSE POWER of a steam-engine is usually computed in the following manner.

RULE.

Find the diameter of the piston, in inches; square the amount, and multiply that square by ·7854. This will yield the area, or the number of square inches which the piston contains.

Multiply the area thus obtained, by the number of feet through which the piston passes in a minute; and the product, by the *effective pressure* of steam, in pounds, on each square inch. By these means, the entire pressure of the steam on the piston will be known.

Finally, divide the pressure by 33,000. This will yield the horses power.

EXAMPLE.

Piston .... 40 ins. diameter.
Speed .... 220 feet per minute.
Effective pressure .... 10 lbs. per inch.

Hence, $40 \times 40 \times {}^{\cdot}7584 = 1256{}^{\cdot}64$ sq. ins. on Piston.
And $1256{}^{\cdot}64 \times 220 \times 10 = 2,764,608$ lbs. effective pressure.

$$\text{And } \frac{2,764,608}{33,000} = 83\tfrac{4}{5} \text{ horses power.}$$

This is the usual method of calculating the power. But when the speed is at 220 feet per minute, the process may be simplified.

RULE 2.

Find by a table of the areas of circles, or by the foregoing rule, the number of square inches contained in the piston. Multiply those inches by the pounds of effective pressure, per square inch; and divide the product by the power of the horse, equal to 150 lbs.

EXAMPLE.

Piston .... 40 ins. diameter
Speed .... 220 feet per minute.
Effective pressure ...... 10 lbs. per sq. inch.

By tables of areas, 40 = 1256·64 sq. ins.

$$\text{And } \frac{1256{\cdot}64 \times 10 \text{ lbs.}}{150 \text{ lbs.}} = 83\tfrac{1}{5} \text{ horses power.}$$

In this example, we neither multiply nor divide by 220 feet. We omit to multiply by the speed of the piston; and we divide by 150 lbs., instead of the action, 33,000. 33,000 is produced, as we have already shown, by multiplying together the power of the horse, 150 lbs., by its speed, 220 feet. It is superfluous, when the speed is at 220 feet, to multiply and divide by the same numbers.

The steam-engine, from which the above calculations have been made, furnished a horse's power for every fifteen square inches of the piston. In Lancashire, and other manufacturing districts, twenty-two square inches are commonly allowed, for engines of certain capacities, But the number of square inches per horse power varies with practical circumstances.

The effective pressure can only be properly determined, by an examination of the several parts of the engine. To take, as is common in practice, any given number of pounds, in engines of the usual construction, and with the ordinary pressure per square inch, as an approximation sufficiently near for calculation, is decidedly erroneous. We shall prove this by our subsequent observations.

We shall now conclude this article with another example.

EXAMPLE 3.

Piston .... 24 ins. diameter.
Speed .... 220 feet per minute.
Effective pressure ...... $6\frac{3}{4}$ lbs. per sq. inch.

By table of areas, 24 ins. = 452·39.

$$\text{And } \frac{452{\cdot}39 \times 6\tfrac{3}{4} \text{ lbs.}}{150 \text{ lbs.}} = 20\tfrac{4}{10} \text{ horses power.}$$

The power of the engine is $20\frac{4}{10}$ horses.

BOILER AND HOT-WATER PUMP.

In the generation of steam, a certain quantity of water is evaporated from the boiler. This or an equal quantity must be again returned to it, by the action of the hot-water pump. It is therefore of consequence, that we should determine the exact amount of water which is thus evaporated. It will enable us to assign to the hot-water pump its proper dimensions.

Heretofore, it has been generally stated, that the boiler requires for this supply ten gallons of water for each horse power in an hour; and we had ourselves, in the "Engineers' Pocket Book," been the means of extending this popular error. We have now much pleasure in being the first to correct it.

Messrs. Horrockses, Miller, & Co. most extensive spinners and manufacturers of cotton, at Preston, in Lancashire, have a most admirably constructed steam-engine, with a cylinder 44 inches in diameter: or, according to the usual estimate, this engine is 80 horses power.

To supply this engine with steam, three boilers are employed; and, during an experiment of three hours' continuance, the quantity of water evaporated from each may be thus stated:—

Boiler 1—22 feet by 8 feet 2 inches, evaporates $7\frac{3}{4}$ inches.
Boiler 2—23 feet by 8 feet .... do. ...... 15 inches.
Boiler 3—20 feet by 7 feet 3 inches do. ...... $8\frac{3}{4}$ inches.

To ascertain the number of cubic feet of water evaporated from these boilers in one hour, we must reduce the quantities into cubic inches; and then divide the sum of the amounts by 3, the number of hours occupied by the experiment, and by 1728, the number of cubic inches contained in a cubic foot.

Boiler 1, $7\frac{3}{4}$ ins. $\times$ (22 ft. $\times$ 12 ins.) $\times$ (8 ft. 2 ins. $\times$ 12 ins.) $=$ 200,508
Boiler 2, 15 ins. $\times$ (23 ft. $\times$ 12 ins.) $\times$ (8 ft. $\times$ 12 ins.) $=$ 397,440
Boiler 3, $8\frac{3}{4}$ ins. $\times$ (20 ft. $\times$ 12 ins.) $\times$ (7 ft. 3 ins. $\times$ 12 ins.) $=$ 182,700

$$\text{And } \frac{200{,}508 + 397{,}440 + 182{,}700}{3 \times 1728.} = 150.59 \text{ cubic feet.}$$

The quantity evaporated, in one hour, was $150\frac{1}{2}$ cubic feet.

The proportions of the various parts, the pressure of the steam, the friction, the entire amount of the columns of water raised, and all things, with the exception of the temperature of the condensing water, are supposed to be the same. But, notwithstanding these, and that the same quantity of coal be consumed, the engine will produce for the proprietor at 80°, an effective or available pressure of 83 and 4-5th horses; at 162°, but 46. The power being reduced to nearly one-half.

Further, let us investigate the effects at other degrees of temperature.

EXAMPLE 1.

Temperature of the water in hot-well 116°:

At 80° $\dfrac{1256{\cdot}64 \times 10 \text{ lbs.}}{150 \text{ lbs.}} = 83\frac{4}{5}$ horses power.

161° $\dfrac{1256{\cdot}64 \times 9 \text{ lbs.}}{150 \text{ lbs.}} = 75\frac{2}{5}$ do.

Loss $8\frac{2}{5}$ horses power.

EXAMPLE 2.

Temperature of the water in the hot-well 142°.

At 80° $\dfrac{1256{\cdot}64 \times 10 \text{ lbs.}}{150 \text{ lbs.}} = 83\frac{4}{5}$ horses power.

142° $\dfrac{1256{\cdot}64 \times 7\frac{1}{2} \text{ lbs.}}{150 \text{ lbs.}} = 62\frac{4}{5}$ do.

Loss 21 horses power.

From these considerations, the necessity of paying strict attention to the temperature of the condensing water is obvious. To bring it to 80°, 86°, 93°, and 103°, respectively, the following quantities of cold water, for each horse power, are required:—

Temp.	*Per minute.*	*Per hour.*	*Loss on Piston.*
At 80° ...	7 gallons ...	420 gallons ...	½ lb. per sq. inch.
86° ...	6 gallons ...	360 do.	⅝ lb. ,,
93° ...	5 gallons ...	300 do.	¾ lb. ,,
103° ...	4 gallons ...	240 do. ...	1 lb. ,,

This will be more clearly understood by the following calculations, in which the quantity of caloric, or heat, contained in the water which is generated into steam, for each horse power, is shown as it is distributed in the condenser.

1. *To condense the steam to* 80°:

$11\frac{3}{4}$ gallons in steam $\times$ 1182° = 13,889°
420 do. of cold water $\times$ 50° = 21,000°

$431\frac{3}{4}$ gallons. 34,889°

Hence, 34,889 $\div$ $431\frac{3}{4}$ = 80°

2. *To condense the steam to* 86°:

$11\frac{3}{4}$ gallons in steam $\times$ 1182° = 13,889°
360 do. of cold water $\times$ 50° = 18,000°

$371\frac{3}{4}$ gallons. 31,889°

Hence, 31,889 $\div$ $371\frac{3}{4}$ = 86°

3. *To condense the steam to* 93°:

$11\frac{3}{4}$ gallons in steam $\times$ 1182° = 13,88°
300 do. of cold water $\times$ 50° = 15,000°

$311\frac{3}{4}$ gallons. 28,889°

Hence, 28,889 $\div$ $311\frac{3}{4}$ = 93°

4. *To condense the steam to* 103°:

$11\frac{3}{4}$ gallons in steam $\times$ 1182° = 13,889°
240 do. of cold water $\times$ 50° = 12,000°

$251\frac{3}{4}$ gallons. 25,889°

Hence, 25,889 $\div$ $251\frac{3}{4}$ = 103°

The average temperature of the cold water is estimated at 50°; and that of the steam at 212° of thermometric, and 970° of latent heat.

COLD WATER WELL AND RESERVOIR.

To effect the condensation of the steam, the water is very commonly raised, by means of the cold-water pump, from a reservoir or well. This absorbs from the engine some portion of its power. Indeed, where the wells are deep, the quantity of power thus expended is so great, that the condensing system can no longer be judiciously applied. This may be known by the following investigations.

RULE.

Multiply the weight of water, in pounds, by the feet through which it passes in a minute; and divide the product by 33,000. The quotient will exhibit, friction excluded, the horses' power expended.

EXAMPLE.

To condense to 103°: weight of cold water, 10lbs per gallon, at 62° of temperature.

Engine, nominal power ...... 4 horses.
Water, per horse power ...... 4 gals. or 40lbs. per min.
Lift of do. or height raised, 230 feet per minute.

$$\text{Hence } \frac{4 \times 40 \times 230}{33,000} = 1\ \tfrac{1}{9} \text{ Horse Power.}$$

In this example, taken from an engine which has been erected, the power consumed by the actual lift of the water is very great—being equal to 1 $\frac{1}{9}$ horse. But if we add to this amount, the loss by the friction of the water in the pipes, the impediments at the valves, and other results, it will not be less than a horse and a third, or one-third of the entire power of the engine—nominally, therefore, the proprietor possesses a four horse engine : practically, it does not exceed two horses and two-thirds.

Under such circumstances, the engineers should have erected a three horse high-pressure engine, on the non-condensing principle; and not a four horse condensing engine. By so doing, the expenses of the well, the difference between the cost of the high and low pressure engines, and the annual difference in the expenditure of fuel, would have been saved.

The preceding remarks appertain, principally, to large towns, where land is too scarce, or too expensive, for the formation of reservoirs. But where land can be obtained at a reasonable rate, reservoirs are, in most cases, desirable. Care, however, should be taken to make them sufficiently large, and to supply them with the requisite quantity of water, to preserve the temperature at its lowest range.

To show the practical utility of reservoirs, we shall have recourse to other examples and illustrations.

EXAMPLE 1.

The temperature of the condensing water to be reduced to 80°: the water to be raised from a well; lift 48 feet.

Engine, nominal power, ... 50 horses.
Water, per horse power, ... 7 gals. or 70lbs. per min.
Lift .... 48 feet.

$$\text{Hence } \frac{50 \times 70 \times 48}{33,000} = 5{\cdot}091 \text{ horses power.}$$

The power absorbed, in raising the water for the condensation, is $5\frac{1}{10}$ horses power.

EXAMPLE 2.

Temperature, to be reduced to 80°, as before: the water to be raised from a well: lift 32 feet.

Engine, nominal power, ... 50 horses.
Water, per horse power, ... 70 lbs. per minute.
Lift, ... 32 feet.

$$\text{Hence } \frac{50 \times 70 \times 32}{33,000} = 3.394 \text{ horses power.}$$

The power is nearly $3\frac{4}{10}$ horses.

EXAMPLE 3.

Temperature to be reduced to 80°, as before; the water to be raised from a reservoir; lift 4 feet.

Engine, nominal power,.........50 horses.
Water, per horse power, ...70 lbs, per minute.
Lift,................................ 4 feet.

$$\text{Hence, } \frac{50 \times 70 \times 4}{33,000} = {\cdot}424 \text{ horse power.}$$

The lost power is rather more than $\frac{4}{10}$ths of a horse.

REMARKS.

Consumed in Example 1......	5·091	horses' power.
in Example 3......	·424	
Saving effected by reservoir...	4·667	horses' power.

Consumed in Example 2......	3·394	horses' power.
in Example 3......	·424	
Saving effected by reservoir...	2·970	horses' power.

By forming a reservoir, therefore, for a fifty horse engine, the power effectively saved, when the lift is 48 feet, is nearly equal to $4\frac{7}{10}$ horses; and when it is 32 feet, to 3 horses, and this is exclusive of friction.

In some cases, the cold water pump must be put down with the engine, to supply, occasionally, the loss in the reservoir by waste and evaporation. But the power thus consumed, at intervals, will be far less than that which would be abstracted by the friction to which we have alluded. It, therefore, cannot interfere with the computations of the power which we have given, as to the saving that may be effected and will accrue to many proprietors of engines, by the adoption of these measures.

Some persons there are, who erect high pressure engines from the supposition that they cannot obtain the requisite supply of water to effect the condensation. This is a very erroneous notion; and we are sorry to remark, that it is exceedingly prevalent with practical men. The sooner it is expunged, the better for their interests.

In the generation of steam, the boiler evaporates, for each horse power, $11\frac{3}{4}$ gallons per hour, or in a day of twelve hours, 141 gallons. In one week, of six working days, the quantity evaporated will be 846 gallons, and in six weeks, 5076.

$$\text{For } 11\tfrac{3}{4} \text{ gals.} \times 12 \text{ hours} \times 36 \text{ days} = 5076.$$

In high-pressure non-condensing engines, the whole of this water is discharged from the cylinder into the atmosphere, in the state of vapour; so that we must consider it as irrecoverably lost to the proprietor of the engine.

To condense the steam to 80°, or to half a pound pressure on each square inch of the piston, there will be required for each horse power, per minute, 7 gallons of cold water: if the temperature is to be reduced to 103° only, or to one pound pressure, 4 gallons will be sufficient. The seven gallons will amount to 5040, and the four gallons to 2880 in a day.

For 7 gals. × 60 min. × 12 hours = 5040
And 4 gals. × 60 min. × 12 hours = 2880

By these results, we learn that the water evaporated from the boiler for each horse power, and expelled from the cylinder into the atmosphere, as waste, is, in rather more than three weeks, sufficient to condense the steam to 103°, and in six weeks to 80° of temperature. These remarks are founded upon the supposition that no portion of the water is returned a second time to the condenser, during the same day of twenty-four hours; and that the high pressure boiler does not evaporate a greater quantity for each horse power than a boiler of low pressure.

PIPES, ANGLES, AND BENDS.

In the construction of the steam-engine, the steam and eduction pipes are, usually, not well proportioned to the cylinder. Some engineers assign to a thirty-inch cylinder, steam and eduction pipes of six inches diameter; others extend the diameters to eight inches. But in neither case are the proportions judiciously applied. This may be known by comparing the areas, or the number of square inches contained in each.

	Diameter.	Area.
Cylinder	30 ins.	707 ins.
Steam and exhausting pipes	6 ins.	28¼ ins.
Ratio 1 to 25.		
Cylinder	30 ins.	707 ins.
Steam and exhausting pipes	8 ins.	50¼ ins.
Ratio 1 to 14.		

In the proportions which we have first exhibited, the relative capacities of the pipes and the cylinder are as 1 to 25; in the second as 1 to 14. The sizes of the first, therefore, are much more detrimental to the interests of the proprietor of the engine, than those of the second. But, as we have before remarked, the relative proportions of both are far from correct.

The steam is generated in the boiler to a certain amount of pressure, and it is then conducted to the cylinder through the steam pipe, which not unfrequently ranges through a considerable distance, and possesses numerous flexures, angles, and bends. How is it possible, then, after passing through this pipe, which is only one-fourteenth, or one twenty-fifth part of the area which it is ultimately to occupy, and after encountering the friction and the impediments to which we have alluded, for the steam to press on the piston with the same effective force as it exerts in the boiler?

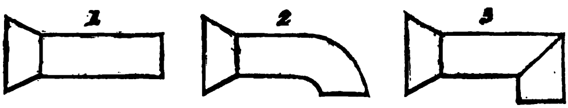
The loss, so far as the steam-pipe is concerned, results from the friction of the steam against the sides of the metal, and from the impediments and re-action at the several flexures, angles, and bends. But in the exhausting pipe, the same loss is compounded with imperfect condensation.

When the exhausting valve opens, the steam should *instantaneously* flow into, and be condensed in, the condensing vessel. The passages, therefore, should bear a much nearer relation to the proportions of the cylinder. These proportions may readily be assigned by any skilful engineer.

Since first we made, publicly, these remarks, we have known many engines to be altered; and we have the satisfaction of knowing, that some have been increased in power four horses, and others as high as thirteen. The increase was, of course, somewhat dependent on the capacities of the engines, and the imperfections in the original construction.

ANGLES AND BENDS.

Power is very commonly absorbed from the engine, and sometimes to a great extent, by causes which are, practically, but little known: we allude to the angles and bends in the various pipes.



If three tubes be made, of equal diameters and equal lengths, and shaped as above, the time occupied in discharging a certain quantity of water from each, may be thus expressed:—

No. 1, or straight tube..................45 seconds.
2, or bent tube ....50 ...
3, or angular tube ....70 ...

These results are from the experiments of M. Venturi. By them we learn to obviate many practical defects. Right angles should be avoided as much as possible; and bends, although well curved, should be but sparingly introduced.

The tubes, by which the experiments were conducted, were 15 inches in length, and 14½ lines in diameter—twelve lines being equal to one inch. The French inch is somewhat larger than the English, being 1·09, consequently, in English measure, the length of the tubes was 16 and 1-3rd inches; and the diameter rather more than an inch and three-tenths.

RADIATION OF HEAT.

It is surprising that, in the present advanced state of science in many of our manufacturing districts, so little attention should be paid, by the proprietors of engines, to the rapid evolution of caloric by radiation.

In many parts the boilers are exposed freely to the atmosphere, and to the atmospherical changes—wind, rain, and snow, are permitted to act upon the external surface of the metal,

which forms the crown of each boiler; and a large portion of the heat, or caloric, which had been absorbed into the vessel, in the production of steam, is thus released again, and transfused into the surrounding media.

Those proprietors who have, with greater judgment, erected boiler-houses, are, in other respects, not unfrequently deficient. Large open ways in the front of the boilers, and unglazed apertures for the admission of light, give the winds free access to the still uncovered crowns, and egress to the passage of caloric.

The boilers, the steam-pipes, and the cylinder, are also painted black;—betraying either great ignorance, or great indifference, with respect to this quality, and to pecuniary interest.

Leslie discovered, by experiments made in 1802, that the heat emitted by radiation was affected by the nature of the surface exposed:—the quantities radiated, in a given time, being in the following proportions:—

Tin,	blackened, ...	100°.
	clean, ...	12°.
	scraped bright, ...	16°.
Lead,	clean, ...	19°.
	grey crust, ...	45°.
Steel Plate,	....	15°.

And our ingenious and scientific friend, Mr. William Taylor, of Preston, has found the radiation from a black open vessel, in a warm room, sufficient to reduce the temperature of the water within it, from 212° to 176°, in two minutes.

These observations point out the necessity of surrounding the several surfaces by which the steam is inclosed with non-conducting substances—as pounded charcoal, or pounded coke; covering the boilers and steam-pipes, in such manner, as shall confine the heat; and of having recourse to a coating of white, and not of black, paint, when the surfaces are covered.

EXPANSIVE STEAM.

The expansive properties of steam are but little understood, and very rarely applied to practice, in manufacturing districts. In Cornwall, and sometimes the southern parts of the kingdom, the application is attended with highly beneficial results. But it should be stated that this system can be introduced, with much greater advantage, in engines that are employed in the raising of water, than in those which are devoted to manufacturing purposes. In these last, the power is opposed to a continually varying resistance; while in the former, the resistance is commonly the same, or of equal intensity.

To the proprietor of a pumping engine, we would advise the adoption of the expansive system to an almost unlimited extent—even to the exclusion of any further ingress of steam to the cylinder, after the piston had passed through but one-eighth or one-ninth of its stroke. But to a manufacturer, our observations must be more strictly confined.

By these remarks, we do not wish to imply, that the manufacturer should not have recourse to its application: on the contrary, we have known instances where it has been introduced, by our own suggestion, and where a considerable saving, in the economization of fuel, has been effected by it. All that we wish to enforce is, that it cannot be carried to the same extent in a manufactory as in a lifting engine, without producing an inequality of motion.

Expansive steam may be thus explained:—If we allow steam to flow into the cylinder of a steam-engine until the piston be depressed to one-half of the stroke, and then prevent the admission of any further quantity, the piston will, if the engine be properly weighted, continue its motion to the bottom. The pressure of the steam, so long as the supply be continued from the boiler, will be equal, we will suppose, to ten pounds upon the inch. With this force it will act upon the piston until it completes one-half of the stroke: the further supply of steam will then be excluded, and that which is in the cylinder will expand as the piston descends, so that, when the stroke is

completed, it will occupy the entire capacity. The pressure of the steam will then be half of its former amount, or five pounds upon the inch.

During the descent of the piston, the pressure of the steam does not suddenly decrease from ten pounds to five; but it gradually declines, through the successive intervals, until at the final point it yields that force. It is by this gradual expansion and diminution of pressure, that the superior action is produced.

RULE.

Divide the length of the stroke, by the length of the space in which the dense steam is admitted, and find the hyperbolic logarithm of the quotient.

To that quotient, add unity or 1. The amount will exhibit the ratio of the gain.

EXAMPLE.

Length of the stroke, ... 6 feet.
Steam admitted, ... $1\frac{1}{2}$ foot.

Hence, $6 \div 1\frac{1}{2} = 4$; hyp. log. $4 = 1{\cdot}386$.
And $1{\cdot}386 + 1 = 2{\cdot}386$.

If the same quantity of steam had been allowed to act upon the piston of a steam-engine, without expansion, the action would have been 1—it is now 2·386; being in the ratio of 1000 to 2386.

The following table shows the gain that will result, by "cutting off" the steam at different parts of the stroke:

$\frac{1}{2}$ Stroke,	....	1·69.
$\frac{1}{3}$ do.	....	2·10.
$\frac{1}{4}$ do.	....	2·39.
$\frac{1}{5}$ do.	....	2·61.
$\frac{1}{6}$ do.	....	2·79.
$\frac{1}{7}$ do.	....	2·95.
$\frac{1}{8}$ do.	....	3·08.

To change common logarithms into the hyperbolic, multiply by 2·3026.

ROADS AND RAILWAYS.

The power of the horse is, as we have before stated, equal to the raising or carrying of 150 lbs., through 2½ miles in an hour.

By exerting this amount of force, it can, on the average, and under the ordinary vicissitudes of the weather, draw on the turnpike-road about 14 cwt. nett, or 30 cwt. gross:—on the improved or raised railway, such as that between Liverpool and Manchester, from 12 to 19 tons.

The exertion of the animal is, throughout, the same: the difference in the amount of useful action is dependant on the opposing forces, or the obstacles with which it has to contend.

When drawing on the turnpike road, its power is opposed to the friction between the axle and the nave, between the sides of the wheel and the ruts into which it sinks, and between the periphery of the wheel and the ground. Besides these, there are the several stones, pieces of dirt, and the like, which form, with the wheel, a series of inclined planes; and there is the continuous inclined plane, produced by the gradual sinking of the earth, beneath the wheel, ultimately forming the rut through which it passes.

In the raised or improved railway, some of the most important of these opposing forces are withdrawn. The wheel, resting on a firm and substantial basis, can no longer sink into ruts; and no longer has it to contend with a series of inclined planes—consequently, the horse exerts its strength, simply against the friction between the nave and the axle, and the periphery of the wheel and the rail. The railway, therefore, is proportionately superior to the road.

The opposing forces, on the railway, vary from the 180th to the 280th part of the power. In other words, a man, boy, or horse, or any other power whatever, by exerting a pound, can move along the line from 180 to 280 times the quantity. The horse, therefore, by the due exertion of its strength, can draw these amounts multiplied by 150. For the power of the horse, when producing the maximum of effect, is equal to 150 lbs.

The effect produced by the horse on the railway, under various opposing forces, may be thus expressed:—

HORSE POWER.

$\frac{1}{180}$th, ... 180 lbs. $\times$ 150 lbs. $=$ 12 tons.

$\frac{1}{200}$th, ... 200 lbs. $\times$ 150 lbs. $=$ $13\frac{1}{4}$ tons.

$\frac{1}{240}$th, ... 240 lbs. $\times$ 150 lbs. $=$ 16 tons.

$\frac{1}{280}$th, ... 280 lbs. $\times$ 150 lbs $=$ 19 tons.

gross weight, drawn by the horse through $2\frac{1}{2}$ miles per hour, or 25 miles per day.

The great difference in the amount of labour, varying from 12 to 19 tons, results, principally, from the simplest of causes, and one that is much disregarded. It is the greater or less attention paid to the lubricating substance, interposed between the axle of the wheel and the nave, to diminish the friction. When the requisite care is bestowed, by frequently cleansing the parts, employing oil of a good quality, and often renewing it, the horse will draw about 19 tons; under other circumstances, the effect may be reduced to 12 tons.

This diminution of effect, by inattention to the unctuous or fatty matter, commonly interposed between surfaces in motion, was first pointed out by Coulomb—it has been lately verified by the experiments of Mr. Nicholas Wood, who conducted a series of experiments on a heavily weighted axle, resting on its bearings. When the bearings were clean, and the oil continually renewed, the axle made 252 revolutions by the descent of a weight through a given distance; but when the oil was allowed to remain, and was not supplied with any additional quantity, 37 revolutions only were produced by the same expenditure of power. Similar effects result in vehicles of draught.

Having shown the quantity of gross weight, which the horse can draw along the improved railway, it is necessary, for the clear perception of the subject, that we determine, as near as the variations in practice will admit, the nett amount.

The waggons, for the transit of merchandize, on the Liverpool and Manchester Railroad, weigh, respectively, about 28 cwt. If the goods conveyed by them, were of the same specific gravity, or of equal weight, bulk for bulk, the difference between the gross and nett amounts might readily be assigned.

But as great variations do result, we can only furnish amounts that are approximative. We believe, however, that these will be found as nearly correspondent with the effects of practice, as can, under the circumstances, be obtained.

Op. Force.	Gross.	Waggons.	Net Weight.
$\frac{1}{180}$th.........	12 tons —	$4\frac{1}{4}$ tons =	$7\frac{3}{4}$ tons.
$\frac{1}{200}$th.........	$13\frac{1}{4}$ tons—	$4\frac{3}{4}$ tons =	$8\frac{1}{2}$ tons.
$\frac{1}{240}$th.........	16 tons —	$5\frac{1}{2}$ tons =	$10\frac{1}{2}$ tons.
$\frac{1}{280}$th.........	19 tons —	7 tons =	12 tons,

drawn by the horse through $2\frac{1}{2}$ miles per hour, for 10 hours daily.

From the foregoing investigations we can determine the ratios, or show the relative amount of horse power that must be expended, both on the turnpike-road and on the improved railway, to draw through a given distance the same weight of merchandize.

Op. Force.	Railway.	Road.	Ratio.
$\frac{1}{180}$th.........	12 tons :	$1\frac{1}{2}$ ton : :	8 : 1.
$\frac{1}{200}$th.........	$13\frac{1}{4}$ tons :	$1\frac{1}{2}$ ton : :	$8\frac{5}{6}$: 1.
$\frac{1}{240}$th.........	16 tons :	$1\frac{1}{2}$ ton : :	$10\frac{2}{3}$: 1.
$\frac{1}{280}$th.........	19 tons :	$1\frac{1}{2}$ ton : :	$12\frac{2}{3}$: 1.

By this tabular arrangement we are apprized, that one horse on the railway, when the opposing forces are equal to the 180th part of the weight, can produce as much effective labour, or draw as great a weight through any given distance in a day, as can be accomplished by eight horses on the turnpike-road. And when the opposing forces are such as are afterwards stated, the $\frac{1}{200}$th, the $\frac{1}{240}$th, and the $\frac{1}{280}$th part of the weight, one horse, on the railway, will perform as much, as $8\frac{5}{6}$, $10\frac{2}{3}$, and $12\frac{2}{3}$ horses on the road respectively. The differences, so far as power is concerned, being decidedly in favour of the general introduction of railways.

MAN POWER.

In forming railways between manufacturing and commercial towns, we are of opinion that greater attention should be paid to the introduction of the power of men, in lieu of horses.

By these remarks we do not intend to imply that the power of men should wholly supersede the power of horses: that would be a strange conclusion. But that certain provisions should be made for the introduction of man power along the line.

The power of man, when working to the maximum of effect, we have stated at p. 24, to be equal to $27\frac{1}{4}$ lbs. or rather more, 27·273 lbs. By exerting this force he can draw on the railway the following quantities:—

Op. Force.

$\frac{1}{180}$th.........180 lbs. × 27·273 lbs. = 2·19, or $2\frac{1}{5}$ tons.
$\frac{1}{200}$th.........200 lbs. × 27·273 lbs. = 2·44, or $2\frac{1}{2}$ tons.
$\frac{1}{240}$th.........240 lbs. × 27·273 lbs. = 2.92, or $2\frac{9}{10}$ tons.
$\frac{1}{280}$th.........280 lbs. × 27·273 lbs. = 3·41, or $3\frac{4}{10}$ tons

gross weight, through $2\frac{1}{2}$ miles per hour, for 10 hours, or through 25 miles per day.

We know that some political economists have expressed themselves decidedly averse to the direct application of the power of man to purposes of draught. But such persons can know but little of the animal organization, or of the causes which influence physical derangement. A man, generally speaking, experiences much better health when employed in the open air, walking through a given distance per day, and with a certain weight adapted to his powers, than when confined to any sedentary occupation. Boatmen and porters are employed in direct action; why, therefore, should not the exertions of others be similarly disposed? The opinions of medical men, we doubt not, will accord fully with these observations.

To those who have not pursued investigations on animal strength, 25 miles per day will appear a great distance for a

man to pass through, taking one working day with another. Nor can a man be brought immediately into this kind of labour. But it will be found, eventually, that this mode of applying his strength is attended with advantages.

Such being the case, we think it probable, that the power of man will, at no distant period, be more generally employed, on these lines of transit. Merchants, manufacturers, and traders, do not require, very frequently, to send more than a ton, or from that to 2½ tons, of merchandize, at any one time; and they require that certain commissions should be executed in the town, to which those goods are sent. Suppose, therefore, that a man be thus employed on a railway, between Manchester and Bolton, or Leeds and Bradford, he can draw the weight along the line,—deliver the goods at their destination,—execute the various commissions entrusted to him—and return to his employer in the evening, with another load: whereas, if recourse were had to the usual means of transit, the delivery, and the execution of the various orders, would be dependant upon many persons, and strangers; it is, therefore, not unlikely, that some of them would be more or less neglected.

STEAM POWER ON RAILWAYS.

The application of the power of steam on the railway, for the transit of passengers and merchandize, renders it of some consequence to the engineer, as also to the proprietors of the line, that they should be able to calculate, with precision, the quantity of steam power that will be required to draw a given weight, with a given speed. We know that numerous erroneous notions have been promulgated on this subject. We, therefore, the more readily avail ourselves of the information which we possess, to establish data.

RULE.

Ascertain, by an examination of the line, the construction of the engine, and the attention paid to the lubrication of the axles, the amount of opposing forces.

Divide the weight to be drawn, by the tons which the horse can move, at the rate of $2\frac{1}{2}$ miles per hour; and multiply the quotient by as many times as the velocity of the engine, along the line, will exceed that speed. The product will yield the horses power.

EXAMPLE 1.

Opposing Force	$\frac{1}{180}$ th of weight.
Weight to be drawn	60 tons gross.
Speed along the line	10 miles per hour.

$\frac{1}{180}$ th, op. force, $=$ 12 tons through $2\frac{1}{2}$ miles.

Speed, 10 miles $\div$ $2\frac{1}{2}$ miles $= 4$.

Hence, 60 tons $\div$ 12 tons $= 5 \times 4 = 20$ horses power.

The power of the steam-engine, to move 60 tons gross along a railway, at the rate of 10 miles per hour, is 20 horses.

EXAMPLE 2.

Opposing Force	$\frac{1}{240}$ of weight.
Weight to be drawn	128 tons gross.
Speed along the line	$7\frac{1}{2}$ miles.

$\frac{1}{240}$ th, op. force, $=$ 16 tons at $2\frac{1}{2}$ miles.

Speed, $7\frac{1}{2}$ miles $\div$ $2\frac{1}{2}$ miles $= 3$.

Hence, 128 tons $\div$ 16 tons $= 8$; and $8 \times 3 = 24$ horses power

In this second example, the power will be 24 horses.

REMARKS.

We have before had occasion to remark, that the horse power of the steam-engine, and that of the living animal, has been, heretofore, but imperfectly understood.

When we were at Liverpool, some few months since, the Samson and Goliah engines drew from that town to Manchester 1013 bales of New Orleans cotton, weighing 186 tons, at the rate of $12\frac{1}{2}$ miles per hour. This was considered at the time, to be an astonishing performance; and it was currently stated, that no engineer could have anticipated the result.

To show that such conclusions were erroneous, we pursued the following investigations:—We determined, in the first place, by the preceding rule, the weight drawn by the Samson engine, its speed, and its power; and then compared the effect, with that which would have been yielded, mechanically, by an equal number of horses. The subjoined will exhibit the result:—

SAMSON ENGINE.

Weight of 30 waggons, at 28 cwt. each,	42 tons.
Weight of engine and tender, ...	16
Weight of cotton and packages, ...	86
	144 tons.

The gross weight drawn by the engine, according to this statement, was 144 tons.

We then compared this weight with the power:

Number of cylinders, ...	2
Diameter of each piston, ...	14 inches.
Pressure of steam per inch, ...	50 lbs.
Speed of periphery of wheels, ...	$12\frac{1}{2}$ miles.

Hence, by Rule, page 35,

$$14 \times 14 \times \cdot 7854 \times 2 \text{ pistons} = 307 \cdot 8768 \text{ square inches.}$$

$$\text{And } 307 \cdot 8768 \times 50 \text{ lbs.} = 15{,}393 \cdot 84 \text{ lbs.}$$

$$15{,}393 \cdot 84, \text{ less one-third for friction, \&c.} = 10{,}262 \cdot 56 \text{ lbs.}$$

$$\text{And } \frac{10{,}262 \cdot 56 \text{ lbs.}}{150 \text{ lbs.}} \quad 68\tfrac{2}{5} \text{ horses power.}$$

Having, by these calculations, ascertained the number of horses power possessed by the Samson engine, we proceeded to investigate the quantity of power that ought, mechanically, to have been expended. This was proved, by dividing the weight, 144 tons, by the several amounts which the horse can draw, under the various opposing forces:—

$\frac{1}{240}$th .... 144 tons $\div$ 16 tons $=$ 9 horses.
$\frac{1}{200}$th .... 144 tons $\div$ $13\frac{1}{4}$ tons $=$ 11 horses.
$\frac{1}{180}$th .... 144 tons $\div$ 12 tons $=$ 12 horses.

When the speed is at $2\frac{1}{2}$ miles per hour.

But the speed was 5 times that, or $12\frac{1}{2}$ miles per hour. Hence 9, 11, and 12 horses, respectively, multipled by 5, will yield 45, 55, and 60 horses of mechanical power, under those varying circumstances.

Finding, therefore, by our investigations, that, the opposing forces were at $\frac{1}{180}$ part of the weight; and, consequently, that it would require but 60 horses power; and further finding, that the Samson engine possessed the power of $68\frac{2}{3}$; we concluded, and publicly stated our opinion, that we had been misinformed on the amount of weight that had been actually drawn. We had the pleasure of learning, subsequently, that our conclusions were correct: that the statement should have been presented thus:—

Weight of 30 waggons, 28 cwt. each,	42	tons.
Weight of engine and tender, ...	16	
Weight of 540 bales of cotton, ...	106	
	164	tons.

Hence, we learn that the horse power accords in both cases.

For, $\frac{1}{180}$th op. force, 164 tons $\div$ 12 tons $=$ $13\frac{2}{3}$ horses.
And $13\frac{2}{3} \times 5$, for speed $=$ $68\frac{1}{3}$ mechanical power.
Samson engine, ... $68\frac{2}{3}$ horses power.

We make these observations, to point out the practical value of the tables and investigations which we have presented in this work.

It should be stated, as highly honourable to the directors of the Liverpool and Manchester Railway, that they gave every facility and encouragement to the obtaining of the required data.

RAILWAYS AND CANALS.

In examining railways and turnpike roads, we are accustomed to regard the power with reference to the gross weight that is moved:—On the canal, on the contrary, the motive force is usually computed from the nett weight. In order, therefore, to compare with each other, the canal and the railway, we must reduce both to the same standard.

At pages 52 & 53, we have exhibited, by tabular arrangement, the gross and nett weights that can be drawn by a horse, through 2½ miles per hour, or 25 miles per day. We must now multiply those amounts by the 25 miles, to obtain the action, or the quantities that can be drawn by a horse through 1 mile per day. This may be thus accomplished:—

$\frac{1}{180}$ th ...... 180 lbs. × 150 lbs. × 25 miles = 300 tons.
$\frac{1}{200}$ th ...... 200 lbs. × 150 lbs. × 25 miles = 335 tons.
$\frac{1}{240}$ th ...... 240 lbs. × 150 lbs. × 25 miles = 402 tons.
$\frac{1}{280}$ th ...... 280 lbs. × 150 lbs. × 25 miles = 469 tons.

drawn by the horse through 1 mile per day, on the railway.

The foregoing exhibits the actions for gross weight; we will show the same actions, when the weights are nett:—

Op. Force.	*Gross.*	*Waggons.*	*Nett.*	*Miles.*	*Action.*
$\frac{1}{180}$ ...	12 tons —	4¼ tons =	7¾ tons ×	25 =	193¾ tons.
$\frac{1}{200}$ ...	13¼ tons —	4¾ tons =	8½ tons ×	25 =	212½ „
$\frac{1}{240}$ ...	16 tons —	5½ tons =	10½ tons ×	25 =	262½ „
$\frac{1}{280}$ ...	19 tons —	7 tons =	12 tons ×	25 =	300 „

nett weight, drawn by the horse, on the improved railway, through 1 mile per day.

Proceeding with our inquiry, we must put in juxta-position with these statements, the actions on the canal.

Mr. Bevan states that, by exerting a force of 77 lbs., a boat, loaded with 21 tons of cast iron, was moved along a canal, at the rate of 2½ miles per hour.

To determine the amount of action by this statement, and thence the weight which each horse can draw along the canal, we must reduce the tons into pounds, and divide the amount by the power that was exerted.

$$\text{Hence, } \frac{21 \text{ tons} \times 2240 \text{ lbs.}}{77 \text{ lbs.}} = 611 \text{ opposing force.}$$

$$\text{And } 611 \times 150 \text{ lbs.} = 41 \text{ tons.}$$

By Mr. Bevan's experiments, according to this mode of estimation, the horse can draw on the canal, when proceeding at its maximum speed, 41 tons.

We have frequently had occasion, both publicly and privately to speak in terms of admiration of the talent and ingenuity which this gentleman usually displays in his investigations ;—and we are sorry to be obliged to differ from him in the present instance. We must, however, express it to be our opinion, that either in the construction of the dynamometer, or from some other cause, the experiments were erroneously conducted. For we know that, practically, the horse does not draw 41 tons along the canal, when moving at the speed above stated. The nett weight commonly varies from 20 to 24 tons.

Fortunately, Mr. James Walker has presented to the Royal Society the results of a series of experiments on the same subject. By these we learn, that to move 2 tons along a dock, at about $2\frac{1}{2}$ miles per hour, an expenditure of force equal to 10 lbs. was necessary.

$$\text{Hence, } \frac{2 \text{ tons} \times 2240 \text{ lbs.}}{10 \text{ lbs.}} = 448 \text{ opposing force.}$$

$$\text{And } 448 \times 150 \text{ lbs.} = 30 \text{ tons.}$$

The horse, when thus employed, will, according to the investigations of Mr. Walker, draw about 30 tons.

With this statement we cordially agree. It approaches much nearer to the results of practice; and would, if horses of the average strength were employed on the canal, we have no doubt, coincide with them.

But on this line of transit, when we are making comparisons between mechanical force and that of the living animal, we must make allowance for the indifferent qualities of the animals

employed. When horses are rendered almost unfit for any other kind of exertion, they are not uncommonly placed on the banks of a canal. How far this is judicious, we leave to the investigations of the proprietors.

On the turnpike-road and railway, the horse can pass through 25 miles per day. On the canal, when exerting its maximum strength, not more than 20. The difference is produced by the stoppages at the locks, the badness of the road, and the angular direction of the towing line. The towing line is generally too short; it forms too sharp an angle with the boat; consequently some portion of the power of the horse is opposed to the continued action of the rudder. The animal would proceed much more freely, and exert a greater quantity of effective labour, if the rope were of greater length.

Having, by these inquiries, ascertained the amount of effective force on the canal, when good horses are employed, we shall exhibit the relative value of railway and canal conveyance, per horse power, when the animals are moving at their maximum speeds, or at $2\frac{1}{2}$ miles per hour :

RAILWAY.

$\frac{1}{200}$th, average opposing force, $=$ $212\frac{1}{2}$ tons.

CANAL.

30 tons $\times$ 20 miles, $=$ 600 tons.

So, by the expenditure of a given power, 600 tons net may be moved along the canal with the same facility as $212\frac{1}{2}$ tons along the railway; one horse on the canal yielding as much useful labour as three horses on the railway.

The cost of conveying merchandize along the separate lines is dependant, partly on the nature of the motive force, and partly on the time occupied by manual labour.

To examine these in detail, we shall suppose that 120 tons, net weight, are to be sent by canal and by railway through 30 miles of distance. On the canal, the horse, when working to the average of his strength, can accomplish 20 miles per day; on the

railway, twenty-five. The time occupied, in the one case, is, a day and a half; in the other, a day and a fifth. The account therefore, as near as we can determine, will stand thus:—

CANAL.

4 boats, each containing 30 tons, and navigated by 2 men and 1 boy,

At $2\frac{1}{2}$ miles per hour.

Keep of 4 horses, $1\frac{1}{2}$ day, at 3s. 6d. per day......	£1	1	0
Wages of 8 men and 4 boys, $1\frac{1}{2}$ day, at 3s. 6d. per day each man, and the 4 boys being considered as equal in cost to 1 man	2	7	3
	£3	8	3

RAILWAY.

12 horses, each drawing 10 tons net, and attended by one man,

At $2\frac{1}{2}$ miles per hour.

Keep of 12 horses, $1\frac{1}{5}$ day, at 3s. 6d. per day ...	£2	10	5
Wages of 12 men, $1\frac{1}{5}$ day, at 3s. 6d. do..........	2	10	5
	£5	0	10

At $7\frac{1}{2}$ miles per hour.

Keep of 36 horses, $\frac{2}{5}$ day, at 3s. 6d................	£2	10	5
Wages of 12 men, $\frac{2}{5}$ day, at 3s. 6d................	0	16	10
	£3	7	3

As the statement is thus exhibited, it appears that, when the transit is conducted on both lines, at $2\frac{1}{2}$ miles per hour, the cost of conveyance on canal is much cheaper than by railway. But that, if the speed on the railway be carried to $7\frac{1}{2}$ miles per hour, the cost is nearly equal.

This is the manner in which the statements would be viewed, by those who are not acquainted with the diminution of animal power, at increased rates of speed. We will, however, show the statement as it would occur in practice.

To proceed at $7\frac{1}{2}$ miles per hour, a lighter horse, such as is usually applied to stage coaches, must be employed. This horse proceeds at a quicker speed, but does not exert so much useful labour.

A stage coach, on the improved mode of construction, weighs from 18 to 22 cwt., and when loaded with passengers and luggage, about forty-eight. When working to a maximum, the horse, by exerting 150 lbs., can draw along the turnpike-road 30 cwt. Hence, the effective labour, to move forward the stage coach, its passengers and luggage, is 240 lbs.

For 30 cwt. : 150 lbs. : : 48 cwt. : 240 lbs.

Each horse on the average exerts 60 lbs.; and, when proceeding at the rate of 9 miles per hour, does not pass through more than 13 miles in a day (*see p.* 80.) At $7\frac{1}{2}$ miles he may perhaps, in his daily exertion, accomplish 15 miles.

Under these circumstances, the statements should be thus exhibited:—

Weight of coach, passengers, &c.............48 cwt.
Horses employed at a time .... 4 ...

Hence, $48 \div 4 = 12$ cwt. each horse.

Average draught of each coach horse ....12 cwt.
Distance passed through per day...............15 miles.

Action, $12 \times 15 = 180$, at $7\frac{1}{2}$ miles per hour.

Average draught of cart horse..................30 cwt.
Distance passed through per day...............25 miles.

Action, $30 \times 25 = 750$, at $2\frac{1}{2}$ miles per hour.

Draught of each horse on railway ....10 tons.
Weight to be drawn ....120 tons.

Hence, as 750 : 10 tons : : 180 . 2·4 tons.

And 12 tons $\div\ 2\frac{4}{10}$ tons $=$ 50 horses' power.

To draw 120 tons along the railway, at $7\frac{1}{2}$ miles per hour, 50 horses, therefore, would be required. The cost of conveyance would be as follows:—

At 7½ miles per hour.

Keep of 50 horses, 1 day, at 3s. 6d. per day ...	£8	15	0
Wages of 12 men, ⅖ day, at 3s. 6d. do..........	0	16	10
	£9	11	10

The time occupied in the transit is two-fifths of a day; but the horses, from their great exertion, accomplish a day's labour. The men, on the contrary, are only occupied during the transit, and their wages are charged accordingly.

Mechanical power is now most commonly adopted on railways, and it may with propriety be introduced on canals, when the speed is not to exceed 2½ miles per hour. Hitherto the application of steam-power on canals has been invariably associated in the mind with high rates of speed. But this is not desirable. Steam power, with slow motion, will be found much cheaper than horse power; it will supersede the labour of many men; and the destruction of the embankments will be more than counterbalanced by the saving effected in the annual repairs of the towing path. For the towing path will then be rendered unnecessary.

When mechanical power is employed in both cases, and both are moving at the rate of 2½ miles per hour, the conveyance by canal, as we have before stated, will be cheaper than the railway, in the proportion of 1 to 3. And should higher rates of velocity take place on the railway, the results will be still more favourable to canal proprietors.

The canal-boats, to produce the greatest interest for the shareholders, ought to proceed at the rate which we have assigned. Higher velocities are attended with much more than proportionate expenses, whatever the power employed.

Canals are only adapted to conveyance at slow rates of motion. When high velocities are required, the railway will be found the cheapest mode of transit.*

* The investigations of our ingenious and talented friend, Mr. Fairbairn, of Manchester, and the observations of Mr. Grahame, in reply to Mr. Wood, will be noticed in our intended larger publication, in 2 vols. 8vo.

WATER WHEELS.

The power and effect of different kinds of wheels, and of wheels of similar form, will be materially influenced by the modes of construction and arrangement. But the wheels made by the best millwrights are sufficiently near, in practical results, to admit of the judicious application of theoretical investigation.

OVERSHOT WHEEL.

The water should never be discharged on the apex of the wheel; but at an angle of 45°, or from that to 52½°. When discharged on the apex, the water has no tendency, whatever, to impart to the wheel a rotary motion:—on the contrary, its gravity increases the friction at the axles, and deducts from the power.

The speed of the periphery should be from 6½ to 8½ feet per second. Mr. Smeaton, in his "*Experimental Inquiry,*" states 3 feet. But this celebrated engineer was aware, at a later period of his life, that he had computed the speed erroneously; and to some wheels which he subsequently erected, in Cornwall, he gave the speeds which we have stated.

When the wheel is judiciously made, 100 lbs. of power will produce 66 lbs. of effect.

The following will exhibit a mode of calculating the power:

RULE.

Multiply the number of feet through which the periphery of the wheel passes in a minute, by the water discharged upon it, in the same time, in pounds; and divide the product by the following numbers. The quotient will exhibit the effect:

Divided by 9,150 = man power.
by 50,000 = horse power.

The wheel must not, in this calculation, be connected with the machinery that it is intended to impel.

EXAMPLE.

Speed of periphery = 6 feet per second.
Water discharged = 600 gals. per minute.

Hence, 6 feet $\times$ 60 seconds = 360 feet per minute.

And 600 gals. = 6000 lbs.

$$\frac{6000 \times 360}{50,000} = 43\tfrac{1}{5} \text{ horses' power.}$$

UNDERSHOT WHEEL.

The velocity of the periphery of an undershot wheel should be equal to one-third, or from that to half the velocity of the stream; the float-boards should be so constructed as to rise from the water at right angles with its surface; not more than half of each float should be below the water; and from 3 to 5 should be immersed at the same time, according to the magnitude of the wheel. When the wheel is judiciously made, 100 lbs. of power will produce 32 lbs. of effect.

RULE.

Multiply the pounds of water discharged through the race-course, in a minute, by the feet through which the periphery of the wheel moves in the same time: and divide the product by the subjoined numbers. The quotient will exhibit the men or horses' power.

Divide by 18,750 = man power.
by 103,125 = horse power.

This wheel, similarly to the overshot, must be released from its machinery.

Speed of periphery 3 feet per second.
Water discharged 8000 lbs. per minute.

$$\text{Hence, } \frac{8000 \times 3 \times 60''}{103.125} = 14 \text{ horses' power.}$$

BREAST WHEEL.

The breast wheel partakes of the nature of both the overshot and undershot;—and its power may be calculated by paying attention to its construction, and to the preceding rules.

EXPOSITION OF FALLACIES.

The impetus which has been given, within these last few years, to mechanical inquiry, has been productive of some brilliant, and highly useful discoveries, in the silk, the cotton, the woollen, the flax, and in the various other departments of our manufacturing industry ; and in our largest and best engineering departments, to some of the most extraordinary specimens of mechanical ingenuity and combination.

But these discoveries, and the authors of them, have been allowed, with but few exceptions, to pursue their destined ways, without being much known beyond the sphere of their applications, and without receiving from the public that meed of praise which is unquestionably their due.

Pretended discoverers, however, have arisen ; and by far too abundantly. These, aided by patent-agents, and by various periodical publications, have been permitted to engross, and do still receive, much of the public time and attention. Their names—or at least the names of many of them—are as familiar with all classes of society, as are the names of some of the most distinguished benefactors of our species ; and, consequently, many persons have been induced to invest large sums of money in schemes, which are as fallacious in their prospects, as ruinous in their consequences.

It is a difficult and a thankless task, to endeavour to withdraw the veil of delusion, from the eye-sights of those individuals, who have already expended large sums of money, in the hope of acquiring great riches, by the successful prosecution of schemes. But we know the difficulties with which we have to contend—we know that it is a peculiar characteristic of the human mind, to endeavour to deceive itself—to bring forward specious arguments to support itself in its fallacies, and to flatter itself with the notion that that which it would have, is sure to be realized.

We shall, however, proceed boldly with the task, knowing that, eventually, truth will triumph over error.

SMALL BOILERS.

The contemplated introduction of small boilers is one of the most extraordinary fallacies which has been engendered in the mind.

Small boilers are designed principally for locomotive purposes. But some are intended, by the patentees, to supersede the larger kind employed in manufactories. With respect to the former, we can perceive no beneficial results that are likely to accrue, either on the railway, or the turnpike road: and in the manufacturing establishments, it is found, by practical experience, that it is much more profitable to extend, rather than to diminish, the sizes of the boilers most commonly adopted.

We have already stated, page 37, that $11\frac{3}{4}$ gallons of water must be evaporated in every hour, to impart to the engine a horse's power. Suppose, therefore, that a twenty horse engine be employed,—the quantity evaporated in an hour will be 235 gallons, or 2350 lbs. This will occupy $37\frac{3}{5}$ cubic feet.

Hence, if we add to this quantity, an equal space above the surface of the water, for the steam chamber; and half the quantity of water, in addition, to protect the metal from the destructive action of the fire, at the expiration of the time; then the cubical content of the boiler should not be less than 94 feet.

Cubical content for evaporation,	$37\frac{3}{5}$	feet.
for protection,...	$18\frac{4}{5}$	„
for steam room,	$37\frac{3}{5}$	„
	94	„

If the boiler be made of less proportions, the requisite supply of water must be drawn behind the engine in a tender, or it must be supplied from water-stations, in times proportionately short. In other words, the water-stations, with the accompanying pumps, reservoirs, tanks, and manual assistants, must be at less distances apart.

Independently of the inconveniences and expenses which would be thus produced, a loss would ensue from increased consumption of fuel. For, when the boiler is small, and the

area of the surface exposed to the action of the fire is less than the usual proportions, there must be a rapid draught; and a rapid draught will not allow of sufficient time for the absorption of the whole of the caloric into the boiler.

Caloric flows through the pores of a vessel in equal quantities in equal times. (*See page* 32.) Hence, a rapid draught will carry through the effluent passage of the chimney some portion of that caloric which ought to be retained as power. The temperature in the chimney ought not to exceed the temperature of the steam.

Two eminent engineers, Mr. Vignoles and the late Mr. Nimmo, have issued a public document on this subject. It is with reference to the quantity of water that was evaporated, during some experimental investigations, from a small boiler, of a peculiar construction—its content being 65 cubic feet. The fire was maintained at a high degree of intensity by an artificial draught, produced by rotating fans.

These gentlemen state, that 41½ cubic feet of water were evaporated from this boiler, in an hour, by the consumption of 252 lbs. of coke. And, in allusion to this subject, they make the following observations:—

"From which it appears, that only 6 lbs. of coke per cubic foot of water per hour was consumed, and the evaporation of *a cubic foot of water per hour being generally considered the measure of a horse power*, the conclusion is, that the boiler is a forty horse boiler, and that the quantity of fuel requisite to work it is 2¼ cwt. per hour, the expense of which is 12¾d., and as the consumption diminishes after the first hour, the expense of fuel will probably not exceed 1s. per hour for the forty horse boiler."

It is with feelings of regret, that we find ourselves under the necessity of expressing an opinion which is at variance with the opinions of such talented men. But as this statement is likely to lead to erroneous conclusions, not only with the party most interested in the boiler to which it alludes, but also with others, who may, from time to time, pursue similar experiments, we must express our dissent to its accuracy.

The evaporation of a cubic foot of water, per hour, is *not* the measure of a horse power. At page 38, we have shewn, by experiment, that $11\frac{3}{4}$ gallons is necessary. A cubic foot of water is $6\frac{1}{4}$ gallons. The statement, therefore, should appear thus:—

Cubic foot of water	=	$6\frac{1}{4}$ gallons.
Evaporated per horse power	=	$11\frac{3}{4}$,,
Evaporated in experiment	=	$41\frac{1}{2}$ cubic feet.

$$\frac{41\frac{1}{2} \text{ cubic feet} \times 6\frac{1}{4} \text{ gallons.}}{11\frac{3}{4} \text{ gallons.}} = 22 \text{ horses' power.}$$

From this, we must deduct two horses' power, for the production of artificial draught.

Hence, the boiler yields only 20 horses' power of effective pressure; and the consumption of fuel, per horse power, is double the amount stated by Messrs. Nimmo and Vignoles. The consumption agrees very closely with that of the best boilers on the Liverpool and Manchester Railway, constructed on the ingenious principle established by Mr. Booth, the treasurer.

ENGINES OF HIGH PRESSURE.

With small boilers, another fallacy is closely interwoven: the contemplated introduction of engines, working with steam generated under high degrees of temperature, and consequently possessing great elastic force.

By these introductions, the patentees propose to effect a saving in the first cost of an engine—in the space which it will occupy —and in the more expensive article, the consumption of fuel.

The fuel, however, is the primary object of consideration. For the annual interest on the original investment of capital, and the sums withdrawn by the gradual depreciation of the property, are comparatively but of little moment.

These errors have arisen in the first place from an examination of the various tables which have been published, on the elastic force of steam: and more especially from the table furnished by Mr. Woolf.

TABLE.

330.—*Showing the Elastic Force of Steam, from* 212 *to* 320 *degrees of Temperature.*

BY MR. PHILIP TAYLOR.

Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.
212	30·00	234	40·60	256	65·50	278	94·70	300	133·75
213	..	235	45·50	257	66·60	279	96·26	301	135·60
214	31·00	236	46·40	258	67·75	280	97·75	302	137·55
215	..	237	47·30	259	69·00	281	99·25	303	139.75
216	32·30	238	48·20	260	70·12	282	100·70	304	141·90
217	33·00	239	49·10	261	71·25	283	102·20	305	144·05
218	33·70	240	50·00	262	72·45	284	103·80	306	146·15
219	34·20	241	50·90	263	73·52	285	105·60	307	148·30
220	35·00	242	51·75	264	74·80	286	107·30	308	150·65
221	35·50	243	52·62	265	76·00	287	109·00	309	157·70
222	36·20	244	53·50	266	77·25	288	110·80	310	155·00
223	37·00	245	54·40	267	78·50	289	112·65	311	157·20
224	37·50	246	55·30	268	79·80	290	114·50	312	159·45
225	38 00	247	56·25	269	81·14	291	116·40	313	161·75
226	38·80	248	57·20	270	82·50	292	118·30	314	164·20
227	39·50	249	58·20	271	83·90	293	120·25	315	166·70
228	40·20	250	59·12	272	85·45	294	122·20	316	169·15
229	40·85	251	60·10	273	86·95	295	124·15	317	171·70
230	41·55	252	61·12	274	88·50	296	126·05	318	174·30
231	42·25	253	62·15	275	90·00	297	128·00	319	176·80
232	43·00	254	63·20	276	91·55	298	129·80	320	179·40
233	43·75	255	64.40	277	93·15	299	131·62		

By this table, we perceive that, to generate steam at a pressure of 30 inches of mercury in a vacuum, 212° of heat are necessary; to double that pressure, or to raise the barometric column to 60 inches, 251°; and to raise the pressure to 120 inches, or to quadruple the original force, the temperature will be 293°.

$$\begin{array}{rlcl} 30 \text{ inches} & \text{pressure} & = & 212^\circ \\ 60 \text{ inches} & \text{do.} & = & 251^\circ \\ 120 \text{ inches} & \text{do.} & = & 293^\circ \end{array} \left.\begin{array}{l} \}\ 39^\circ \text{ difference.} \\ \}\ 42 \quad \ldots \end{array}\right.$$

Hence, the addition of thirty-nine degrees of heat increases the pressure from 30 inches to 60; and by adding 42° more, the force ascends to 120 inches.

Thus far, the statement appears exceedingly favourable to the projectors of high-pressure engines; and this aspect is continued under the observations of Mr. Woolf.

Mr. Woolf has stated, that a quantity of steam having the force of 5, 6, 7, or more pounds on every square inch of the boiler, may be allowed to expand itself to an equal number of times its own volume, when it will still have a pressure equal to that of the atmosphere.

From the results in the table by Mr. Philip Taylor, many persons have inferred that, if 212° of heat be necessary to produce steam at 30 inches pressure, and only 39° more be required to raise the power to 60 inches, then, it must be much more economical to generate steam at the pressure which is last-mentioned, than at the first. But this is not the case.

Mr. Watt and Mr. Southern conducted a series of experiments on this subject; and found, if the sensible heats, above stated, were added to the latent heats of the steam, under those pressures, that the caloric, to yield a certain force, was a constant quantity. This accords with our own investigations, that double the quantity of caloric is necessary, to produce double the pressure; and that, if the pressure is to be quadrupled, the influx of heat must be four times its former amount. As, therefore, the pressure of steam depends upon the quantity of heat contained within it, in a sensible and latent state, high-pressure steam-engines will invariably be found to consume more coal than engines of low pressure, of similar construction, and similar power. This we have had ample opportunities of proving, practically, in the course of our professional engagements.

We have intimated, that high pressure engines will be attended with a greater consumption of fuel. In some engines this is produced, partly by non-condensation, and partly by the

cause which we shall hereafter explain, and which is common to all.

Caloric has a tendency to distribute itself equally throughout space. When the steam is generated at low-pressure, or at about 220°, all the caloric above that temperature will, if the parts be judiciously proportioned, enter into the boiler, and into the composition of the steam. But, if the steam be of high-pressure, the difference between the sensible temperatures, or between the former quantity, 220°, and that at which it is now generated, will, by the same law, pass through the flues of the chimney, and be lost to the proprietor. How exceedingly injudicious, therefore, it is for some persons to contemplate the generation of steam at intense heats!!

With respect to the table furnished by Mr. Woolf, we regret that it should have been allowed to occupy so long the public attention; and we do still more regret, that writers of eminence should injudiciously extol it. We have heard, from unquestionable authority, that Mr. Woolf is himself perfectly aware of its inaccuracy. Unfortunately, he has not taken the same pains to undeceive the public, that he did to promulgate an error.

VAPOURS OF ALCOHOL AND ETHER.

By examining some of the treatises on chemical science, many persons have inferred, that the vapours of alcohol and ether might be beneficially introduced, as the motive power of the steam-engine.

The relative caloric of these vapours, both sensible and latent, is usually thus expressed:

Steam ....212°	boiling point	+	970°	latent heat	=	1182°
Alcohol ......175°	ditto	+	440°	ditto	=	615°
Ether ....112°	ditto	+	302°	ditto	=	414.

The vapour evolved from these liquids, at these respective boiling points, is equal in intensity to the atmospheric pressure. Therefore, as the pressure of each is the same, and as the caloric, in each, is as the numbers 1182, 615, and 414, the supposition is, that by employing the vapour of alcohol, instead of steam, half of the fuel will be saved; and that, by having recourse to the vapour of ether, the diminution of consumption will be in the proportion of 3 to 1.

But this, practically, is not the fact. The power of an engine, or its pressure, seems to be dependant upon the quantity of caloric. This will be understood by the following investigations :—

Density	of Steam,........................	1·00.
	of Alcoholic Vapour,.........	2·30.
	of the Vapour of Ether, ...	3·55.

Consequently, when generated under the same circumstances, to fill vessels of equal capacity, and with equal intensities of pressure, there must be evaporated for every 100 lbs. weight of water, 230 lbs. of alcohol, and 355 lbs. of ether.

Hence, by multiplying the relative densities of these vapours, by their relative latent heats, and by adding to the products their respective boiling points, we find, that the quantities of heat, the intensities of pressure, and the consumption of fuel, must necessarily be the same, whatever the liquid employed.

	Latent Heat.		*Density.*		*Sen. Heat.*		*Total.*
For, Water	970°	×	1·00	+	212°	=	1182°
Alcohol......	440°	×	2·30	+	175°	=	1187°
Ether	302°	×	3·55	+	112°	=	1184°

These investigations have a tendency to prove, that the more expensive kinds of liquid, and the various gases liquefied by

Dr. Faraday, are not likely to supersede the employment of water, in the practical generation of steam.

CONDENSED AIR ENGINES.

Within the last few years, a patent has been obtained for the application of condensed air to locomotive engines and machinery; and we have frequently had occasion to express our opinion, professionally, to various persons who, similarly to the patentee, have imagined that great ad antages would result from it.

As this notion is somewhat prevalent, and as several other patents have been granted for the application of similar principles, we shall proceed to investigate the errors into which the patentee has fallen.

The patentee has published a pamphlet on the subject. In this, at pages 11 and 12, he endeavours to define the horse power, at different rates of speed: and thence, the quantity of mechanical power that is necessary, to propel a stage-coach, its passengers, and luggage, at 10 miles per hour. His statement may be thus shown:—

STATEMENT BY PATENTEE.

Horse, at	$2\frac{1}{2}$ miles per hour,	44,000	action per 1′
	at 10 miles do.	22,000	„
	Minutes in an hour ...	60	
	Horses employed	4	

Hence, at 10 miles per hour, $22{,}000 \times 60 \times 4 = 5{,}280{,}000$.

According to this statement, it only requires an exertion of mechanical power, equal to 5,280,000 lbs. raised 1 foot high, to propel a stage-coach, along the turnpike-road, at the velocity assigned.

The patentee, however, appears to be wholly unacquainted with the facts which he has detailed in the article "ANIMAL STRENGTH." He apparently knows nothing of the great decrease of effective power, when animals are employed at high velocities. And he imagines, because 4 horses are found suffi-

cient, at a time, to convey a stage-coach and passengers, at the required speed, that 4 horses of mechanical power will also be demanded. He is, evidently, not aware, that these horses, from their great exertions, can only pass through 13 miles in a day.

Mechanical power is compounded of weight and motion. If we double the speed, we reduce proportionately the weight. Hence, the statement should appear thus:—

CORRECTED STATEMENT.

Weight of coach, passengers, &c.	50 cwt.
Horse can draw, at $2\frac{1}{2}$ miles	30 cwt.
Speed, in miles, per hour	10
Action of horse, at $2\frac{1}{2}$ miles	33,000 per 1′
Minutes per hour	60

Hence, 50 cwt. $\div$ 30 cwt. $=1\frac{2}{3}$ horse power.

And Speed, 10 miles $\div$ $2\frac{1}{2}$ miles $=$ 4 times increased.

Mechanical power, $1\frac{2}{3}\times 4=6\frac{2}{3}$ horses.

Consequently, $6\frac{2}{3}\times 33{,}000\times 60=13{,}200{,}000$.

The mechanical action is therefore 13,200,000, and not 5,280,000, as the patentee has stated. The increase is as $2\frac{1}{2}$ to 1.

Granting, which is not the case, that the various other details of the pamphlet be correct; that the air may be compressed with safety to 64 atmospheres; and that the weight of the vessels in which the air is to be condensed, be fairly given; then, those weights must be multipled by $2\frac{1}{2}$ for the estimated deficiency of power.

At 32 atmospheres 2170 lbs. $\times\ 2\frac{1}{2}=5425$ lbs.
48 ditto ...... 1890 lbs. $\times\ 2\frac{1}{2}=4725$ lbs.
64 ditto ...... 1400 lbs. $\times\ 2\frac{1}{2}=3500$ lbs.

The weight of these vessels, multiplied by the increased velocity of the mechanical power, will shew the action; which, being divided by the draught of the horse, at $2\frac{1}{2}$ miles per hour, will yield the quantity that will be expended, simply to carry forward the condensing vessels.

Speed, 10 miles $\div$ $2\frac{1}{2}$ miles $= 4$
Draught 30 cwt. $\times$ 112 lbs. $=$ 3360 lbs.

Hence, at 32 Atmos. $\frac{5425 \times 4}{3360} = 6\frac{1}{2}$ horses power.

At 48 Atmos. $\frac{4725 \times 4}{3360} = 5\frac{5}{8}$ " "

At 68 Atmos. $\frac{3500 \times 4}{3360} = 4\frac{1}{6}$ " "

The quantity of mechanical power condensed in the vessels' to propel the stage coach and passengers, is seven horses; but of this $6\frac{1}{2}$ horses power is abstracted, at 32 atmospheres of pressure, to move the air vessels. Hence, by the condensation, the patentee has only obtained one-fourteenth part of the required power.

Independently of this mode of exposing the fallacy of this scheme, there is another of a more important character, inasmuch as it is ultimately blended with the first principles of a science, that is but imperfectly understood, by many of the patentees.

Mechanically, a certain quantity of power must be exerted, to produce a given power. In condensing the air, therefore, to a pressure of 40 horses, an equal quantity of power would be expended, if there were no opposing forces. But the friction of the air in the tubes, both at its ingress and egress—the impediments with which it has to contend by angles, bends, and flexures—the friction of the piston in the cylinder, and of the other moving parts—all deduct materially from that power.

To condense the requisite supply, by manual labour, could not be accomplished, in consideration of the expense: it would be much more profitable to apply steam power directly to the object, than to abstract a portion of its force by this or any other condensing system. The friction and impediments of two engines, instead of one, would have to be deducted from the power.

PADDLE WHEEL OF STEAM-BOAT.

The contemplated introduction of duck's foot, eccentric, and three-throw crank movements, as also a numerous variety of other contrivances, instead of the paddle wheel of the steam-boat engine, is one of the most prevailing of the fallacies of the day.

The paddle wheel is fixed upon its axis in the centre; and the float boards, or paddles, which are distributed around its periphery, are immersed to a certain depth in the water.

If the wheel be made to revolve, while the boat is at rest, each paddle will describe a circle. By this means, the broad or flat part of each float is brought towards the surface of the water at angles more or less obtuse, according to the science displayed in its construction, and to the depth of immersion.

From considering, thus far, the motion, an opinion has been generally entertained, that a great loss of power results from the application; and this opinion, most probably, has been strengthened, by the undulations produced in the water, during the passage of a steam-boat engine.

If we attend minutely to the motion of the wheel, we shall perceive that this notion is erroneous.

The floats describe circles around the axis upon which the wheel is fixed; but as the steam-boat progresses while each revolution is being effected, this circular movement is compounded into the linear motion of the vessel. Hence, the diameter, speed, and immersion of the paddle wheel may be so proportioned to the progressive advancement of the boat, that each float shall enter and quit the water at nearly the best possible angle. The paddle wheel, therefore, is likely to maintain its ground, notwithstanding the proposed innovations.

Independently of these observations, which show that the paddle wheel, when properly proportioned, is well adapted to the purposes to which it is applied, there is another impediment to the introduction of any of the contemplated plans.

Most of them are designed to work upon centres, which cannot possibly withstand the force that is exerted on a paddle, equal, as it sometimes is, to that of a hundred horses.

The undulations of the water, during the passage of a steam-boat engine, are usually attributed to the lift, or "*back-water*;" these, however, are principally produced by the displacement of the successive plates of water, which are brought into contact with, and exposed to, the direct action of the power.

ROTARY OR ROTATORY ENGINES.

In the steam-engine, a massive iron beam is made to vibrate on its axis, or fulcrum. From one end of it descends a rod, to which the piston is attached; from the other, the spear or connecting rod, by means of which, the surplus power of the engine is imparted to the crank, and thence to mill-work or machinery.

As the beam vibrates upon its centre, the piston and connecting rods, being at equal distances from the axis, move through equal linear spaces. But the piston moves upwards and downwards in a straight line, while the extremity of the spear rod, from its connection with the crank, passes through the circumference of a circle. *Hence, the crank describes the semi-circumference of a circle, while the piston moves through its diameter.*

The movement of the piston is regulated by the crank, and that of the last mentioned by the fly-wheel. The crank moves through equal distances in equal times; but not so the piston. For, as the crank passes through the circumference, and the piston through the diameter, the spaces described by the piston must vary in different parts of the stroke. This may be proved geometrically.

Describe a circle with a pair of compasses; mark out the circumference into an equal number of degrees; and draw a series of parallel lines from those dimensions, to the same number of degrees, from the apex, on the opposite side of the circle. The great variations of the differences will then be distinctly seen.

The relative differences, however, may be assigned by computation.

Suppose that the stroke of an engine, or the linear distances passed through by the crank and the piston, be 8 feet; and that the semi-circumference described by the crank be divided into 8 equal spaces, then the differences may be thus exhibited:

	Piston.		*Crank.*		*Ratio.*	
Angle—$22\frac{1}{2}$°......	·33	foot	1·57	foot	1 to $4\frac{4}{5}$	nearly.
45°	·87	...	1·57	...	1 to $1\frac{4}{5}$	,,
$67\frac{1}{2}$°......	1·31	...	1·57	...	1 to $1\frac{1}{5}$	,,
90°	1·50	...	1·57	...	1 to 1	,,
$112\frac{1}{2}$°......	1·50	...	1.57	...	1 to 1	,,
135°	1·31	..	1·57	...	1 to $1\frac{1}{5}$	,,
$157\frac{1}{2}$°......	·87	...	1·57	...	1 to $1\frac{4}{5}$	,,
180°	·33	...	1·57	..	1 to 5	,,

Consequently, the beam has a much greater speed in the middle of the stroke than at either end. At 90° or $112\frac{1}{2}$°, it passes through 1·50, or nearly the same distance as the crank; but from the apex of the circle to $22\frac{1}{2}$°, or from $157\frac{1}{2}$° to 180°, it only moves through ·33 of a foot, or about $4\frac{4}{5}$ of the distance. The nearer, therefore, the crank approaches to its centres, the greater will be the diminution of the speed of the beam; and, ultimately, the crank will move over some portion of its path, while the beam is almost in a state of rest.

Hence, as the speed of the beam is regulated in such manner that it gradually decreases towards the time when it changes the direction of its motion, there is not that loss by the reciprocation which is so currently believed. From this we may infer, that rotary engines are not *desiderata*; and further, that such engines are not likely to supersede the reciprocating, or common beam engine.

STEAM CARRIAGES ON ROADS.

The power of steam has been successfully applied to mine-work, to manufacturing industry, and to locomotive purposes, by road and by railway; and there are many persons who contemplate its introduction on the turnpike-road. But this subject requires consideration.

The prospective advantages in the formation of a railway were of a two-fold nature:—First, the diminution of friction and other opposing forces, by the introduction of the raised rail; and secondly, the probable competition between steam and horse power—the railway being as well adapted for the path of a locomotive engine as the circumstances of the case will admit.

The introduction of steam power on the turnpike-road is a question, which revolves itself into an examination of its comparative cost with horse conveyance. For we cannot enter into the sanguine feelings of those persons, who imagine, that much higher rates of speed will be permitted. On the turnpike-road, numerous passengers, and vehicles of every description, move in both directions of the line; and others are continually entering upon it from the side roads, in various angular directions.

To investigate the probable competition of steam with horse power, on the turnpike-road, we must place in juxta-position the cost by each in conveying a known weight through a given distance.

We can determine the cost by horse labour with sufficient accuracy, by availing ourselves of the information contained in a petition, presented in May, 1830, to the Imperial Parliament, by the proprietors of certain stage-coaches, plying between Liverpool and Manchester, and some of the adjacent places.

By this document we learn, that 709 horses were employed by the petitioners, in the transit of passengers and luggage, by 33 coaches; and that the cost of each horse, on the average, in food, harness, shoeing, stabling, and attendance, amounted to very nearly, but not quite, twenty-one shillings per week. The statement may be thus exhibited:—

Harness for 709 horses at £4 each per year...	£2,836	0	0
Shoeing, iron, and labour to blacksmiths ...	2,127	0	0
Hostlers, 87 men, at £1 each, per week......	4,524	0	0
Rent of stables and coach-offices	1,418	0	0
Hay and corn, at 15s. per week	27,651	0	0
Straw at 2s. 6d. per week each	4,615	0	0
	£43,171	0	0
Deduct value of manure	4,615	0	0
	£38,556	0	0

£38,556 ÷ 709 horses = £54 7s. 7d.

Each horse costs £54 7s. 7d. per year, or nearly 21s. per week.

The distances passed through, on the average, may be thus stated:—

	Coaches.	*Trips.*	*Miles.*	*Distances.*	
Liverpool to Manchester ...	26 ×	2 ×	37 =	1924	miles.
to Bolton	4 ×	2 ×	$33\frac{1}{2}$ =	268	,,
to Wigan	2 ×	2 ×	22 =	88	,,
to St. Helen's ...	1 ×	2 ×	12 =	24	,,
				2304	

$$\text{And } \frac{2304 \text{ miles} \times 4 \text{ horse stage}}{709 \text{ horses}} = 13 \text{ miles.}$$

Each horse, when thus employed, passes through 13 miles per day. At these high rates of speed, the destruction of animal life is so great, that the stock has to be renewed every three years, on the average, at a loss of £15 each horse. The cost averages £30; the sale price £15.

This shows in a striking manner, the loss which results from high velocities, when animals are employed. The draught horse, proceeding at the rate of $2\frac{1}{2}$ miles per hour, can move 0 cwt. through 25 miles in a day: the stage-coach horse, on the other hand, when passing through 10 miles per hour, can only move through 13 miles, 12 cwt. The loss of power

is as $4\frac{4}{5}$ to 1. When mechanical power is employed, the diminution of the weight *inversely*, is in proportion to the increase of speed. Hence, there is not the same loss in mechanical application that there is in horse power.

Stage-coach proprietors pay a certain amount of duty to the government, which will, of course, be charged on steam-carriages, in a similar ratio. Such duty will not be admitted into the computation on either side.

The proprietors purchase and maintain the horses, but the coaches are commonly obtained on hire, the charge being three-halfpence per mile. For this sum, the coaches are lent to them, and kept in repair.

The turnpike dues are nearly two-pence per mile.

Having thus obtained the elements of the computation, we will suppose that a stage-coach, with its passengers, and luggage, is to be conveyed through 39 miles, by horse labour, at the usual velocity. Then, as each horse can move through 13 miles per day, or one-third of the distance, it will require 3 relays of 4 horses each. The expense of the transit, under the circumstances which we have pointed out, will be as follows:—

	£.	s.	d.
Keep of 12 horses, at 3s. each per day,........	1	16	0
Interest on prime cost, £360, for one day, ...	0	1	0
Loss by deterioration of horses, £15 each, or £180, in three years	0	3	3
Hire of stage-coach at $1\frac{1}{2}$d. per mile, ...	0	4	11
Turnpike dues, 48 cwt., at 2d. per mile, ...	0	6	6
	£2	11	8

With this cost, we must compare the charges that would ensue from the application of steam.

The lightest steam-carriage, with its tender, water, and fuel, which has, as yet, performed effective duty on the Liverpool and Manchester Railway, weighs 7 tons 9 cwt.; and the power of its engine assimilates, very closely, with that which will be found necessary for the conveyance of passengers, on the turnpike-road. When, therefore, we consider how much stronger the several parts must be on the turnpike-road, to withstand the continued jerks, and changes of speed, from the inequalities of the ground and from the numerous impediments, we believe, that we considerably underrate the amount, and make allowance to the sanguine projectors to a much greater extent than we ought to do, in the following statement:—

Weight of present stage-coach, ...	22	cwt.
Extra strength of wheels, axles, and various parts, to support the additional weight of four tons, ...	16	,,
Weight of 20 horse boiler, engine, and machinery, ...	37	,,
Water for 20 horse power, at $11\frac{3}{4}$ gallons each per hour, ...	21	,,
Weight of coke, as fuel, ...	16	,,
Weight of passengers, &c. as at present,	28	,,
	7 tons, or 140	cwt.

Thus, the weight of the coach, and its engine, boiler, water, and fuel—the water being calculated for an hour's consumption—will be seven tons:

Weight of carriage, engine, &c.	140	cwt.
Draught of horse on turnpike-road, ...	30	cwt.
Increase of speed from $2\frac{1}{2}$ to 10 miles, ...	4	times

Hence, $\frac{140 \text{ cwt.}}{30 \text{ cwt.}} \times 4$ times speed $= 18\frac{2}{3}$ horses power,

The steam-engine must be of the power of $18\frac{2}{3}$ horses; and if to this we add for the great exertion of the animals at different points of the road—the engine, to overcome the same obstacles and impediments, must be at the power of twenty horses.

The cost of an engine of 20 horses power, with boiler and necessary apparatus, and with the coach, for the accommodation of passengers and luggage, cannot be estimated at less than	£700 0 0
And to this, we must add one-fifth of the amount for an extra carriage, to ply along the road while the ordinary steam-coaches are undergoing repairs. In this item, we make a most favourable allowance to the projectors. For we estimate that an extra carriage will only be required to every five working carriages, ...	£140 0 0
Outlay, or prime cost, ...	£840 0 0

The cost of the repairs of a steam-carriage, or locomotive engine, even when plying on the improved raised railway, such as that between Liverpool and Manchester, forms a very heavy item of expenditure. It amounts to about £800 for every 26,000 miles through which it passes. We shall estimate the repairs of the steam-carriage on the turnpike-road, at the same charge. Thus making another favourable allowance to the projectors, ...	£800 0 0
Add to the above, one-fifth of the amount, for the repairs of the extra carriage, ...	£160 0 0
Repairs in one year, ...	£960 0 0

We estimate the repairs for one year, at £960, inasmuch as in our subsequent calculation of the cost of conveyance, we shall suppose, that each steam-carriage passes through 78 miles per day, or 28,270 miles in a year. The calculation of the cost by horse labour, is only taken at half the distance.

Turnpike dues are commonly charged by weight. If the same plan were to be adopted on the application of steam power, the additional charge for each 39 miles would be twelve shillings and sixpence.

For, as 48 cwt.: 6s. 6d.:: 140 cwt.: 19s.
And 19s. — 6s. 6d. = 12s. 6d.

We will, however, suppose that, in consequence of the additional breadth of tire, and the removal of the horses, the extra charge to be seven shillings.

From these preliminary observations, we can compute the cost of conveying a stage coach, its passengers, and luggage, through 39 miles, by steam power.

	£.	s.	d.
Consumption of fuel by 20 horse engine, calculated at the same charge as on the Liverpool and Manchester Railway	0	9	6
Interest on prime cost, £840, at 5 per cent. per annum, for 39 miles, or ½ day	0	1	2
Repairs, £960 in a year = in ½ a day.................	1	6	4
Depreciation of value—Cost of carriage, £840, will sell at the expiration of 2 years for £300, making the loss £540 in 2 years, or in ½ day	0	14	9
Turnpike dues	0	13	6
Rent and Interest for carriage-houses, sheds, pumps, water stations, &c.	0	3	6
Wages of engineer for ½ day	0	3	0
	£3	11	9

Cost by steam power	£3	11	9
by horse power...	£2	11	8
Loss by the application of steam power......	£1	0	1

The preceding investigations have a tendency to prove, that steam power, in consequence of the repairs, and other incidental expenses, will not be made to supersede horse power on the turnpike road.

We therefore, much regret, that the evidence recently taken before a "Committee of the House of Commons," on this subject, has not been of a more satisfactory nature. The following are the final conclusions of the Committee:

"1. That carriages can be propelled by steam on common roads at an average of ten miles per hour.

"2. That at this rate, they have conveyed upwards of 14 passengers.

"3. That their weight, including engine, fuel, water, and attendants, may be under 3 tons.

"4. That they can ascend and descend hills with considerable facility and safety.

"5. That they are perfectly safe for passengers.

"6. That they are not, and need not be, if properly constructed, nuisances to the public.

"7. That they will become a speedier and much cheaper mode of conveyance, than carriages drawn by horses.

"8. That they admit of greater tire than other carriages, and as the roads are not acted on so injuriously as by the feet of horses in common draught, such carriages will cause less wear of roads than coaches drawn by horses.

"9. That rates of toll have been imposed on steam-carriages, which would prohibit their being used on several lines of road, were such charges permitted to remain unaltered."

After the exposition which we have given of the comparative cost of horse and steam power, we shall, in allusion to the foregoing remarks, simply prove, by reference to article 3, the inaccuracy of the information imparted to the Committee.

Weight of stage-coach, as at present constructed	22	cwt.
Water, as per our remarks, for 20 horse engine	21	„
Weight of coke for do., as fuel	16	„
	59	„

The steam-coach will weigh nearly 3 tons, without adding a single pound of weight, for boiler, engine, and additional strength. Hence, the conclusions of the Commiteee are inaccurate.

FINIS.

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As the ENGINEER'S POCKET BOOK has been attacked a second time, in the MECHANICS' MAGAZINE, in a most unwarrantable, abusive, and scurrilous manner, Mr. Adcock, without having recourse to similar language, takes this opportunity to state, that such attack has been directed against him by Mr. Robertson, the editor, *from motives of personal enmity.* This will be obvious to every impartial reader, by comparing the critiques in the *Mechanics' Magazine* with the *Pocket Book*, and with the following observations :—

1. The table of division by inspection was given by Mr. Adcock, *as approximative*, and as correct to the second decimal within a certain range only. This is stated in the examples.

2. Being approximative, Mr. Adcock did not consider it to be necessary always to mark as 1·0, those fractional parts which were greater than ·5.

3. This table, with the exception of a slight typographical inaccuracy, and notwithstanding the pompous display of pretended errors in the *Mechanics' Magazine*, (vol. 10, pages 396, 397, and 398), is therefore *correct to the extent which Mr. Adcock contemplated, and for such calculations as usually occur in practice.* It is not published in the present editions.

4. The rule at page 95, for finding the areas of long irregular figures, in practice, *is correct.* It is the rule usually adopted by surveyors and others.

5. The second rule for the circular zone, page 96, *also is correct.* The diagram shows it is applied to a zone bisected by the diameter.

6. The table of areas of circles, (pages 108 to 111) *is carried to a sufficient number of decimals.* It is accurate to the 1000th part of an inch in all diameters less than 11¼ inches; the 100th part of an inch in all diameters less than 35⅝ inches; and to the 10th part of an inch throughout the higher numbers.

7. The rule (page 118), for finding the areas of circular segments *is not defective.* It was never intended, as the example proves, to apply to segments greater than a semicircle.

8. The rule, (page 121), for finding the area of a circular zone, *is correct.* The examples show that it only applies to the case where one chord of the zone coincides with the diameter. For other zones, rules are given in page 97.

9. Dr. Hutton's theorems for the centres of gyration (page 142) are given immediately after Mr. Farey's decimal values, and are stated to be quoted from his publication.

10. The decimal points, in the tables of the weight of material, (pages 195 to 203), are typographical inaccuracies, and *cannot possibly mislead.* The tables are thus given—weight of a cubic foot of rain water, in ounces 1·000; in pounds, 62·5. Now every one knows that one ounce is not equal to 62½ lbs.: but that one thousand ounces is another expression for that quantity.

11. The tables for the reduction of weights and measures, pages 61 to 63, and for regular polygons, and regular bodies, pages 131 to 133, *are carried to a sufficient number of decimals.* These tables give accuracy to the 10,000th part of a whole number.

12. The tables, page 56, for well-sinking, *is not inaccurate throughout.* It is calculated for the gallon of 282 cubic inches. Mr. Adcock, however, is sorry to acknowledge to the public, that the following diameters are erroneous:—6 feet should be 173 gallons; 7 feet, 236 gallons; and 10 feet, 482 gallons. But even these are not likely to affect the results in practice. The brick work of a well does not form a perfect cylinder; hence, the numbers given in the table, however accurate for cylindrical vessels, can only be considered as approximative in well-sinking.

Mr. ADCOCK has thus swept away '*the several thousands of errors*' of this *impartial* critic; three only remain, in an elaborate work containing some thousands of data, and those three not pointed out by the editor of the *Mechanics' Magazine.* That the editor, in making his observations, has been influenced by motives of personal enmity towards Mr. Adcock, every unprejudiced or impartial person will be able to determine.

As Mr. Adcock never reads the *Mechanics' Magazine*, containing, as it does, so much trash, and disappointing so much the hopes of many of its earliest and best supporters, it was only through the intervention of a friend, that he became aware of the present attack,—he shall, therefore, not consider it worth his while to notice any subsequent one, even should he be apprized of it. On the contrary, he will treat it with the same silent contempt that he did the first—knowing that an attack, *from such a quarter*, cannot possibly injure him in the opinions of the respectable and thinking portion of the community.

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